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COMPUTERIZED ANATOMICAL MODEL MAN

Paul G. Kase

Martin Marietta Corporation
Denver, Colorado 80201

Contract F29601-69-C-0052

TECHNICAL REPORT NO. AFWL-TR-69-161

January 1970

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

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FOREWORD

This research was prepared by the Martin Marietta Corporation, Denver, Colorado, under Contract F29601-69-C-0052. The research was performed under Program Element 62401F, Project 5877, Task 01, and was funded by the Manned Spacecraft Center, Houston, Texas, of the National Aeronautics and Space Administration.

Inclusive dates of research were February through October 1969. The report was submitted 17 November 1969 by the Air Force Weapons Laboratory Project Officers, Captain James A. Dibiase and Captain Roger S. Case, Jr. (WLBB).

The important contributions of the following persons to the success of this study are gratefully acknowledged: Mr. George Moschinsky, Artist, for the illustrations; Senior Engineers John E. Braly, Thomas J. Sullivan, and Adolph M. Spamer for the model design; Mrs. Lois M. Ryan, Associate Engineer, for MEVDP adaptation and operation; Leonard J. Caranna, M. D., and James D. Gatts, M. D., Medical Consultants; Edward Karnes, Ph.D., subject for anatomical measurements; and Mr. Alva Hardy of NASA Manned Spacecraft Center, Houston, Texas, for his computer graphics checking of the model.

This technical report has been reviewed and is approved.

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ABSTRACT

(Distribution Limitation Statement No. 2)

The Computerized Anatomical Model Man is a detailed representation of the radiation transport properties of the human body. It is to be used for computation of the areal density distribution at specified locations in the body. This information is applicable to dose calculations in natural, weapon, reactor, and other radiation environments. The model has two configurations--standing and seated. Over 2200 individual geometrical shapes have been used to depict the external conformation, the skeleton, and the principal organs. The exterior dimensions are those of the 50th percentile Air Force man; the skeleton and organs were scaled from life-size models to conform to the exterior. The model includes variations of material density and fractional composition by weight due to the principal chemical elements contained in muscle, bone, bone marrow, and organ tissue. The model is compatible with the North American Rockwell Modified Elemental Volume Dose Program. This has been demonstrated by solution of sample problems employing both configurations of the model with the North American Rockwell Program on the CDC 6600 digital computer at the Air Force Weapons Laboratory.

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ILLUSTRATIONS

ILLUSTRATIONS (cont'd)

ILLUSTRATIONS (cont'd)

ILLUSTRATIONS (cont'd)

ILLUSTRATIONS (cont'd)

ILLUSTRATIONS (cont'd)

TABLES

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SECTION I

OBJECTIVES OF THE MODEL MAN

1. INTRODUCTION

The growth of manned space flight has brought new emphasis to the problem of evaluating the effects of radiation on man. Though space flight has had considerable public attention, man may be exposed to various radiation sources other than the natural radiation of space. These sources include weapons, reactors, X-ray generators and radioisotopes. Exposure may occur during combat or in laboratory, industrial, or medical situations, as well as in space. There is a need common to all of these situations. That need is to be able to predict accurately the radiation arriving from the radiation source at a specified location in the body.

Before the advent of space flight, except for wartime or accidents, scrupulous efforts had been made to minimize the exposure of man to radiation. Now, manned missions in space involve planned endurance of radiation so that lengthy missions, such as Apollo Applications (AAP), the large space station, or planetary exploration, can be practical in view of other considerations such as weight.

The trend of manned space flight is shown by the Mercury, Gemini, and Apollo programs. During Mercury the doses were measured in mrad. Warren et al.[1] summarize the radiation doses measured during the Gemini program and those anticipated in the Apollo command and service module (CSM). The largest dose reported so far during the U.S. manned space program occurred during the Gemini X flight when doses on the order of 0.8 rad were measured at the astronauts' chests. The Apollo lunar missions occur during a period of maximum solar flare activity. If one of the more intense solar flares of the last solar cycle were repeated, for instance, that of 12 November 1960, the skin dose within the CSM could be 200 rad. The maximum radiation dose levels acceptable to the AAP are higher. For example, Berry[2] has published a maximum operational dose of 300 rad at a depth of 0.1 mm in the skin for 60-day missions. This dose has been derived from a daily dose limit of 5 rad.

The maximum operational dose is an emergency limit. It could result in harmful inflight response in terms of crew safety and postflight response of delayed radiation injury.

Tentative plans for future AAP missions and for interplanetary exploration show the possibility of individuals remaining in orbit for a year or longer. The AAP mission analysis indicates that the skin and eye doses absorbed during an extended mission might exceed currently accepted allowables.

As the limits of the acceptable radiation dose are approached, the need for precise dose calculation is evident. First, a dose calculation with a simple model of man could indicate arrival at a radiation dose limit when, in fact, this has not occurred. Both the configuration of the spacecraft and the presence of the astronaut have profound effects on the radiation dose. As self-shielding by the body could make an apparently unacceptable mission tolerable, this effect should be considered in the planning of missions where radiation might be a limiting factor. Second, more detailed calculations of radiation doses in man are needed because the larger doses anticipated during long missions could exceed the injury thresholds of specific sensitive organs before reaching the maximum operation dose limits specified by sources such as Berry. Several of the critical dose levels are indicated in a report by Helvey et al.[3] For instance, microscopically detectable changes in the germinal epithelium occur near 25 rad. A dose of 150 rad to the gonads may produce temporary subfertility or sterility. A complete analysis of the radiation dose in hypersensitive regions would account for significant modification of the dose due to self-shielding by the body, and thereby either establish confidence in the safety of the astronaut or determine positively that the mission would cause excessive local doses.

Prior to initiation of this study, a detailed model of the radiation transport properties of man, including the effects of the skeleton and organs, had not been available. It is hoped that the Computerized Anatomical Model Man will be a standard for calculation of radiation doses from space and other sources.

2. MODEL REQUIREMENTS

It is common practice to use large digital computers to process the tremendous number of calculations necessary to evaluate complex shielding configurations. The North American Rockwell Modified Elemental Volume Dose Program (MEVDP) is one of several programs for this purpose.[4] This program is operational at both the Air Force Weapons Laboratory and the NASA Manned Spacecraft Center, Houston. The Computerized Anatomical Model Man is completely compatible with MEVDP and should therefore have considerable utilization.

To interface with MEVDP, the Computerized Anatomical Model Man conforms to two principal requirements. First, the geometrical configuration of the model has been established with combinations of the geometrical shapes recognized by MEVDP. These shapes are the hexahedron - a figure comprised of six planar surfaces: right circular cylinder; sphere; hemisphere; right circular cone, truncated right circular cone, and the ellipsoid - truncated by two or fewer parallel planes. Second, the two punched card decks that represent the standing and seated positions of the man are in the format required for operation with MEVDP. In addition to geometrical data, these cards contain the identity of the shield - a four-digit number, a three-digit number identifying the shield material, the material density, and a number indicating the number of individual shields comprising a composite shield. The details of all of these interface requirements are discussed in Section II, Model Development.

The Computerized Anatomical Model Man depicts the radiation transport properties of the 50th percentile Air Force man. The dimensions and medical information incorporated in the model have been taken in large part from a bibliography furnished by the Air Force Weapons Laboratory at the start of this study. The bibliography is included in this report. This information has been supplemented by literature searches conducted by two medical consultants and by measurements of both living subjects and anatomical models. In order to achieve a complete model of the radiation transport properties of man, the exterior conformation, the skeleton, and the organs are depicted. The objectives of the model development included 0.1-inch accuracy of component location and 0.1-inch accuracy of geometrical data input to the computer. The weight of the model man is within 10% of the weight of the 50th percentile Air Force man. The study objectives also included representation of the man with 500 to 1000 individual shield geometries. However, it was necessary to use over 2200 geometrical shapes to achieve the desired accuracy.

SECTION II

MODEL DEVELOPMENT

1. REFERENCE ILLUSTRATIONS

a. Coordinate and Drawing Systems

All illustrations and computer data are referred to a right-hand, orthogonal 3-axis (XYZ) system defined as follows. The origin of the system is at the top of the head in the left/right plane of symmetry. The Z-axis is vertical and positive down so that the clavicular and transpelvic links of the body joints are intersected as shown in Figure 1. The X-axis is in a horizontal plane pointed forward. The positive Y-axis is directed to the right. With this coordinate system, change from a standing to a seated position entails movement of only the limbs. The head and torso are always in the same position with respect to this coordinate system.

The illustrations made during this study were the master source of dimensions for all numerical data entered on the computer card deck. To ensure consistency, the artist drew each illustration 1/2 life size on a 1/2-inch grid. The origin of all measurements is the origin of the coordinate system. An objective of the study was to locate all components within 0.1 inch of the coordinate system. With the grid chosen, each square represents 1 inch. Dimensions scaled from these drawings are considered accurate to within ±0.01 inch.

b. External Conformation of the Man

The exterior dimensions of the Computerized Anatomical Model Man are principally the 50th percentile Air Force man established by Hertzberg, Daniels and Churchill.[5] This survey reports body size data for 132 measurements of over 4000 Air Force flying personnel. Though more recent documents were included in the government furnished bibliography, this survey was usually the principal source for these documents. Furthermore, Hertzberg measured many more individuals than any of the other investigators. Since the principal objective of the Hertzberg survey was to obtain data for the design of skin-tight flying garments, his information is not always appropriate for design of a model man.

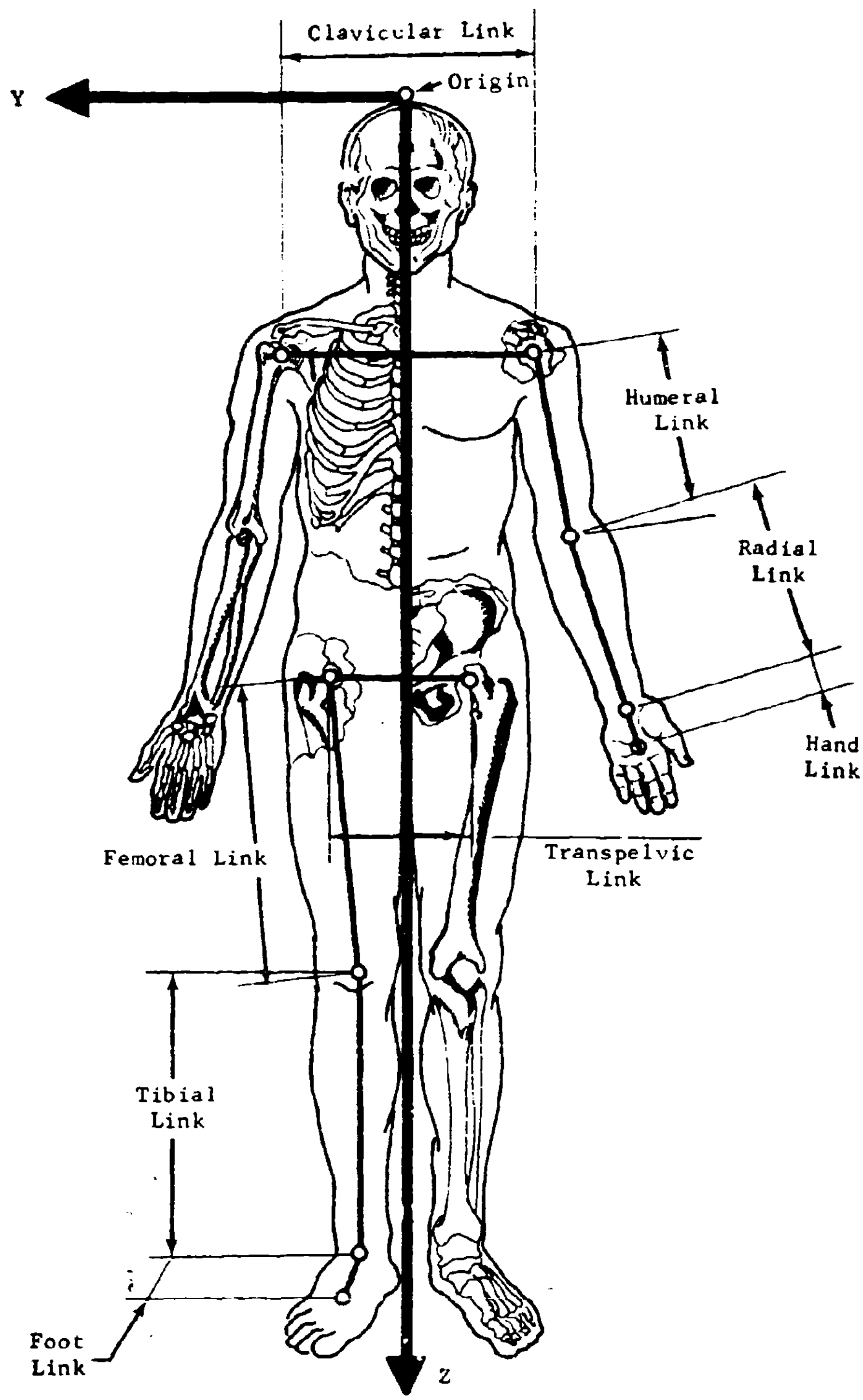


Figure 1 Body Link-Joint and Coordinate Systems

The artist resolved inconsistencies in the Hertzberg data and supplemented the data where necessary with measurements of a living subject who closely approximated the 50th percentile Air Force man. A medical consultant assisted in obtaining these measurements. The artist combined the Hertzberg data, the supplementary measurements, and his experience to produce the exterior layout of the standing man shown in reduced size on Figure 2. Figure 3 shows the differences in appearance of the limbs and genitals of the man when seated.

Symbols and numbers on Figures 2 and 3 show where the Hertzberg data and the illustrations coincide. Table I gives the results of the Hertzberg survey for the 50th percentile man. The numbers on the figures and the numbers in the table are identical. Symbols are also used in Table I to indicate whether the data was used in preparing the illustrations. The reader is referred to the Hertzberg paper for explanation of any measurement nomenclature not clarified by reference to Figures 2 and 3.

c. Skeleton

The bibliography and literature search by the medical consultants provided qualitative or pictorial information describing the skeleton and its location within the body, but specific dimensions for an average man were not available. Therefore, the artist referred to a life-size plastic model skeleton and an assorted set of human bones that had been purchased from the Clay-Adams Scientific Company, New York, and was subsequently borrowed from the Research and Development Division, Martin Marietta Corporation, while preparing the layouts of the skeleton. Figure 4 is a photograph of the skeleton. The assorted bones are shown in Figure 5. The artist referred to Morton[6], Eycleshymer[7], and Grant[8], and was advised by the medical consultants in scaling the model skeleton and developing its conformation within the outline of the 50th percentile Air Force man. The results are shown in Figure 6, the standing position; and in Figure 7, the seated position.

In addition to these front and side views, the artist drew sections of the skeleton at numerous locations. These drawings are presented in Appendix I - Illustrations.

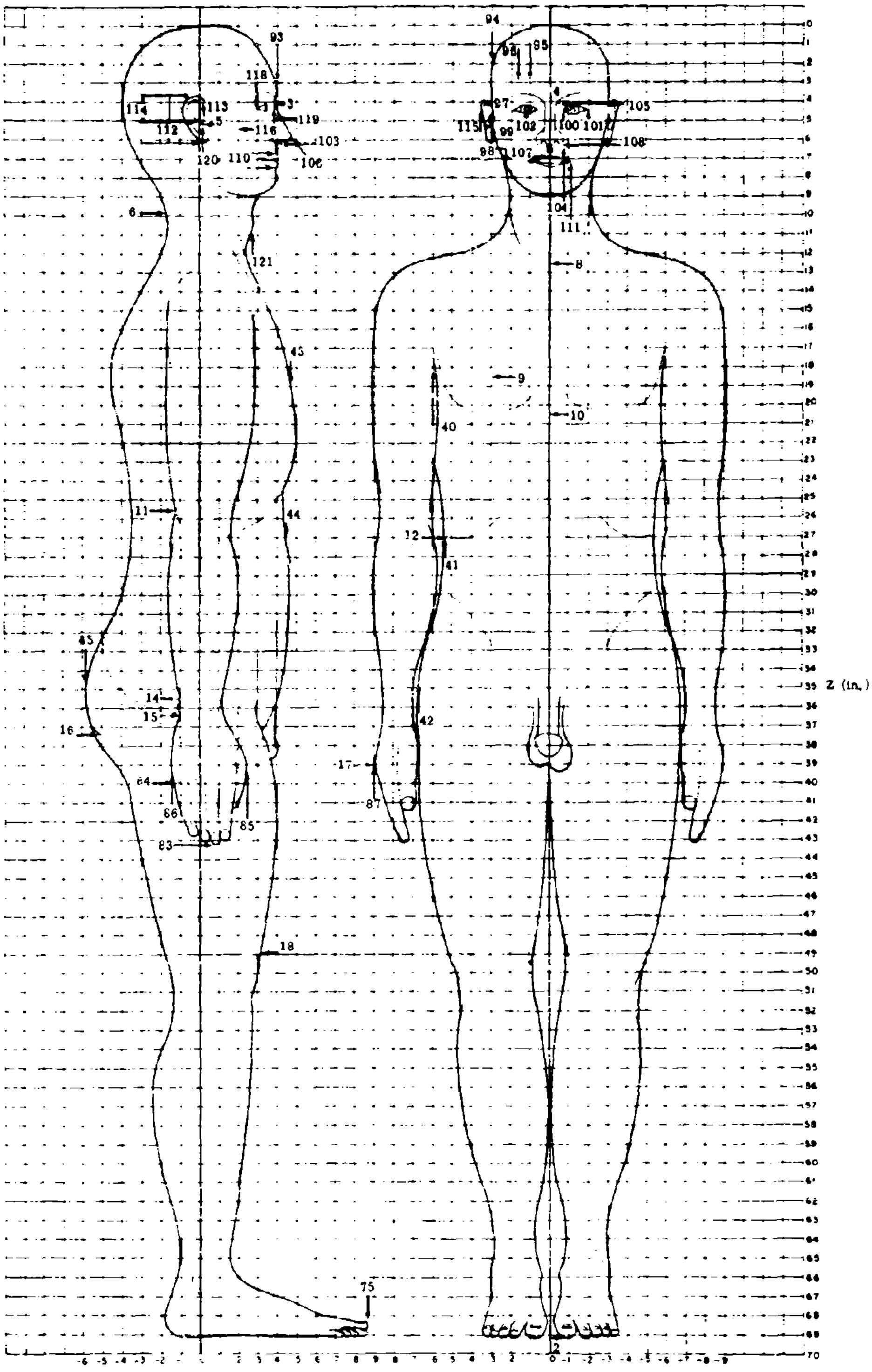


Figure 2 Exterior of the Standing Man

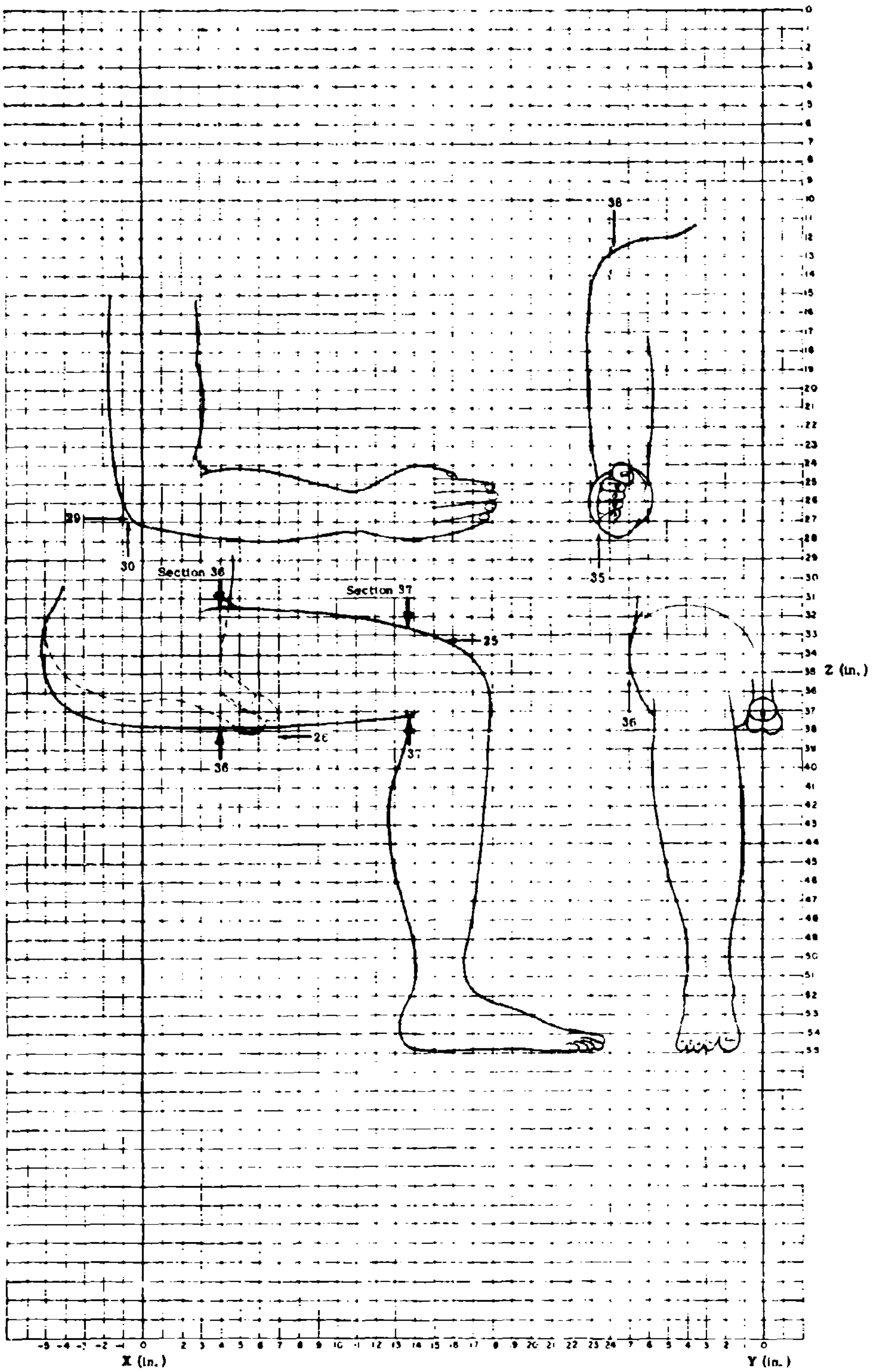


Figure 3 Exterior of the Seated Man

Table I Dimensions of the 50th Percentile Air Force Man

Designation	Dimension	Used X,Y,Z (in.)
Weight		
1. Weight (lb)	161.9	---
Body Lengths		
2. Stature	69.1	Z = 69.1
3. Nasal root height	65.0	Z = 4.1
4. Eye (internal canthus) height	64.7	Z = 4.4
5. Tragion height	64.0	Z = 5.1
6. Cervical height	59.2	Z = 9.9
7. Shoulder (acromial) height	56.6	Z = 12.5
8. Suprasternal height	56.3	Z = 12.8
9. Nipple height	50.4	Z = 18.7
10. Substernal height	48.7	Z = 20.4
11. Elbow height (radiale height)	43.5	Z = 25.6
12. Waist height	42.1	Z = 27.0
13. Penial height	34.5	
14. Wrist height (stylion height)	33.6	Z = 35.5
15. Crotch height (inseam)	32.8	Z = 36.3
16. Gluteal furrow height	31.6	Z = 37.5
17. Knuckle (metacarpale III) height	30.0	Z = 39.1
18. Kneecap (patella) height	20.2	Z = 48.9
19. Sitting height	36.0	
20. Eye (internal canthus) height, -S	31.5	
21. Shoulder (acromial) height, -S	23.1	
22. Waist height, -S	9.3	
23. Elbow rest height, -S	9.1	
24. Thigh clearance height, -S	5.6	
25. Knee height, -S	21.7	ΔZ = 21.7
26. Popliteal height, -S	17.0	ΔZ = 17.0
27. Buttock-knee length	23.6	
28. Buttock-leg length	42.7	
29. Shoulder-elbow length	14.3	ΔZ = 14.3
30. Forearm-hand length	18.9	ΔZ = 18.9
31. Span	70.8	
32. Arm reach from wall	34.6	
33. Maximum reach from wall	38.6	
34. Functional reach	32.3	
Body Breadths and Thicknesses		
35. Elbow-to-elbow breadth	17.2	ΔY = 17.2
36. Hip breadth, -S	13.9	ΔY = 13.9
37. Knee-to-knee breadth, -S	7.9	
38. Biacromial diameter	15.8	ΔY = 15.8
39. Shoulder breadth (bideltoid dia)	17.9	
40. Chest breadth	12.0	
41. Waist breadth	10.6	ΔY = 10.8
42. Hip breadth	13.2	
43. Chest depth	9.0	ΔX = 9.15
44. Waist depth	7.9	ΔX = 7.9
45. Buttock depth	8.8	

Designation	Dimension	Used X,Y,Z (in.)
Circumferential and Body Surface Measurements		
46. Neck circumference	14.9	
47. Shoulder circumference	45.1	
48. Chest circumference	38.7	
49. Waist circumference	31.7	
50. Buttock circumference	37.7	
51. Thigh circumference	22.4	
52. Lower thigh circumference	17.3	
53. Calf circumference	14.4	
54. Ankle circumference	8.9	
55. Scye circumference	18.0	
56. Axillary arm circumference	12.4	
57. Biceps circumference-F	12.8	
58. Elbow circumference-F	12.2	
59. Lower arm circumference-F	11.5	
60. Wrist circumference	6.8	
61. Sleeve inseam	19.8	
62. Sleeve length (spine-to-wrist)	33.7	
63. Anterior neck length	3.4	
64. Posterior neck length	3.6	
65. Shoulder length	6.8	
66. Waist back	17.7	ΔZ = 17.7
67. Waist front	15.2	
68. Gluteal arc	11.7	
69. Crotch length	28.2	
70. Vertical trunk circumference	64.8	
71. Interscye	19.6	
72. Interscye maximum	22.9	
73. Buttock circumference, -S	41.5	
74. Knee circumference, -S	15.4	
The Foot		
75. Foot length	10.5	ΔX = 10.5
76. Instep length	7.6	
77. Foot breadth	3.78	
78. Heel breadth	2.63	
79. Bimalleolar breadth	2.95	
80. Medial malleolus height	3.5	
81. Lateral malleolus height	2.7	
82. Ball of foot circumference	9.6	
The Hand		
83. Hand length	7.5	ΔZ = 7.5
84. Palm length	4.24	ΔZ = 4.2
85. Hand breadth at thumb	4.08	ΔX = 3.90
86. Hand breadth at metacarpale	3.49	ΔX = 3.35
87. Thickness at metacarpale III	1.17	
88. First phalanx III length	2.67	
89. Finger diameter III	0.85	
90. Grip diameter (inside)	1.83	
91. Grip diameter (outside)	4.09	
92. Fist circumference	11.6	

Designation	Dimension	Used X,Y,Z (in.)
The Head and Face		
93. Head length	7.7	ΔX = 7.9
94. Head breadth	6.05	ΔY = 6.1
95. Minimum frontal diameter	4.35	ΔY = 4.35
96. Maximum frontal diameter	4.72	ΔY = 4.72
97. Bizygomatic diameter	5.54	ΔY = 5.54
98. Bigonial diameter	4.3	ΔY = 4.3
99. Bitragion diameter	5.6	ΔY = 5.6
100. Interocular diameter	1.25	ΔY = 1.25
101. Biocular diameter	3.78	ΔY = 3.78
102. Interpupillary distance	2.49	ΔY = 2.49
103. Nose length	2.00	ΔZ = 2.00
104. Nose breadth	1.31	ΔY = 1.38
105. Nasal root breadth	0.61	ΔY = 0.61
106. Nose protrusion	0.90	ΔX = 0.90
107. Philtrum length	0.76	ΔZ = 0.67
108. Menton-subnasal length	2.62	ΔZ = 2.60
109. Menton-crinion length	7.4	
110. Lip-to-lip distance	0.63	ΔZ = 0.73
111. Lip length (bichelion diameter)	2.02	ΔY = 2.00
112. Ear length	2.47	ΔZ = 2.50
113. Ear breadth	1.44	ΔX = 1.20
114. Ear length above tragion	1.17	ΔZ = 1.47
115. Ear protrusion	0.83	ΔY = 0.60
116. Head height (tragion to vertex)	5.1	Z = 5.10
117. Menton projection	1.9	
118. External canthus to wall	6.8	ΔX = 6.8
119. Nasal root to wall	7.8	ΔX = 7.8
120. Tragion to wall	4.0	ΔX = 4.2
121. Larynx to wall	6.9	ΔX = 6.72
122. Head circumference	22.5	
123. Sagittal arc	15.1	
124. Bitragion-coronal arc	13.8	
125. Minimum frontal arc	5.4	
126. Bitragion-minimum frontal arc	12.0	
127. Bitragion-crinion arc	13.1	
128. Bitragion-menton arc	12.8	
129. Bitragion-submandibular arc	12.1	
130. Bitragion-subnasal arc	11.4	
131. Bitragion-posterior arc	10.7	
132. Bitragion-inion arc	11.6	

Note: S - Seated; F - Flexed.
All dimensions in inches except where noted.

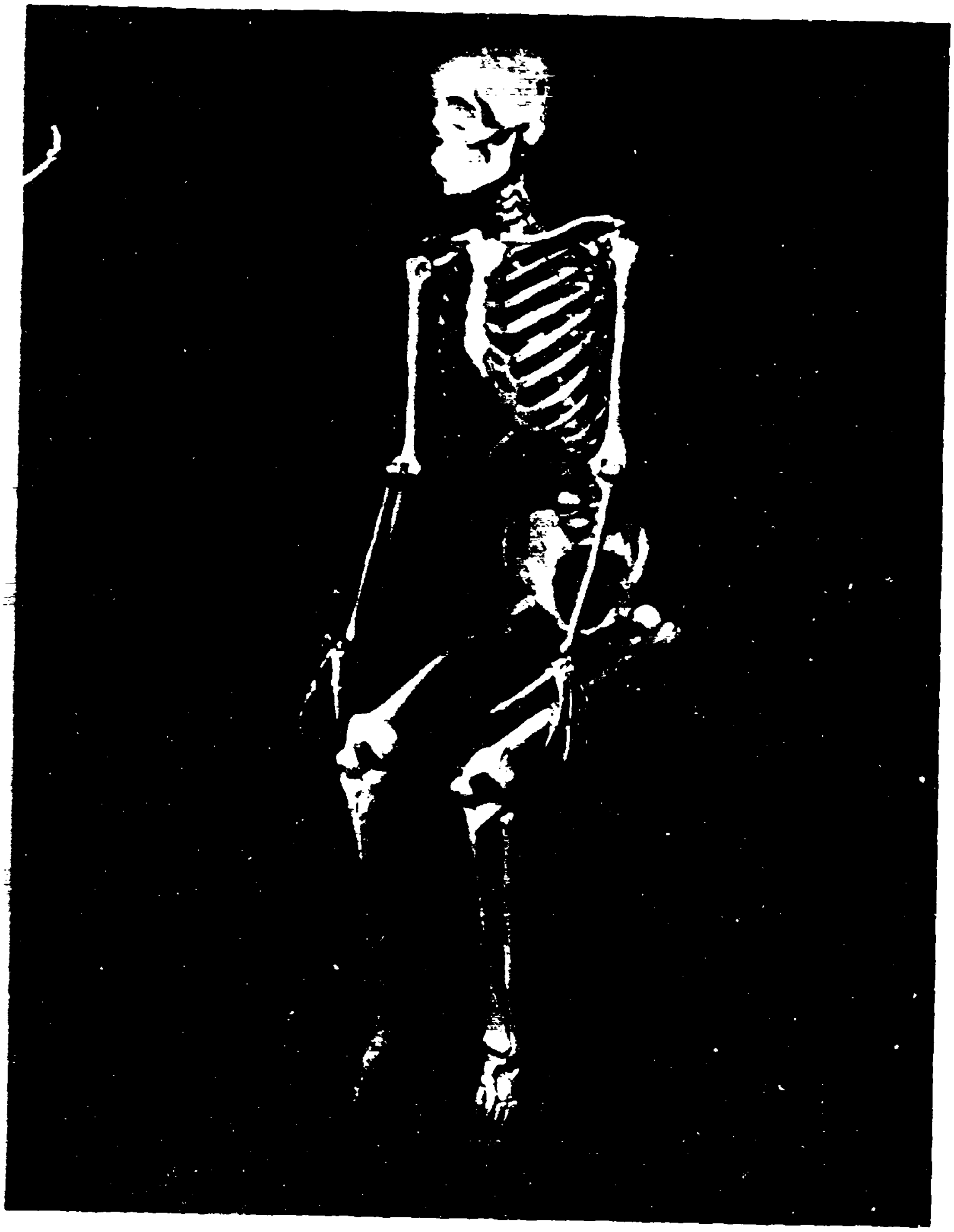


Figure 4 Plastic Model Skelton

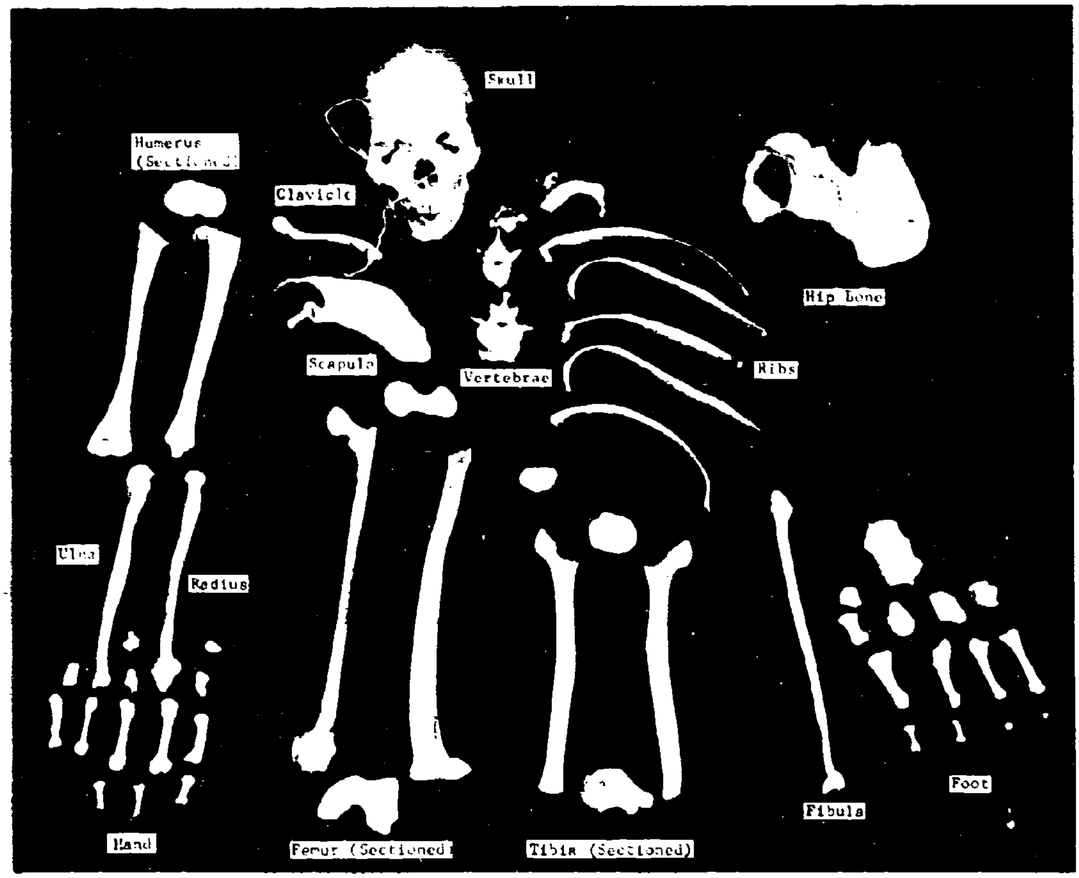


Figure 5 Assorted Human Bones

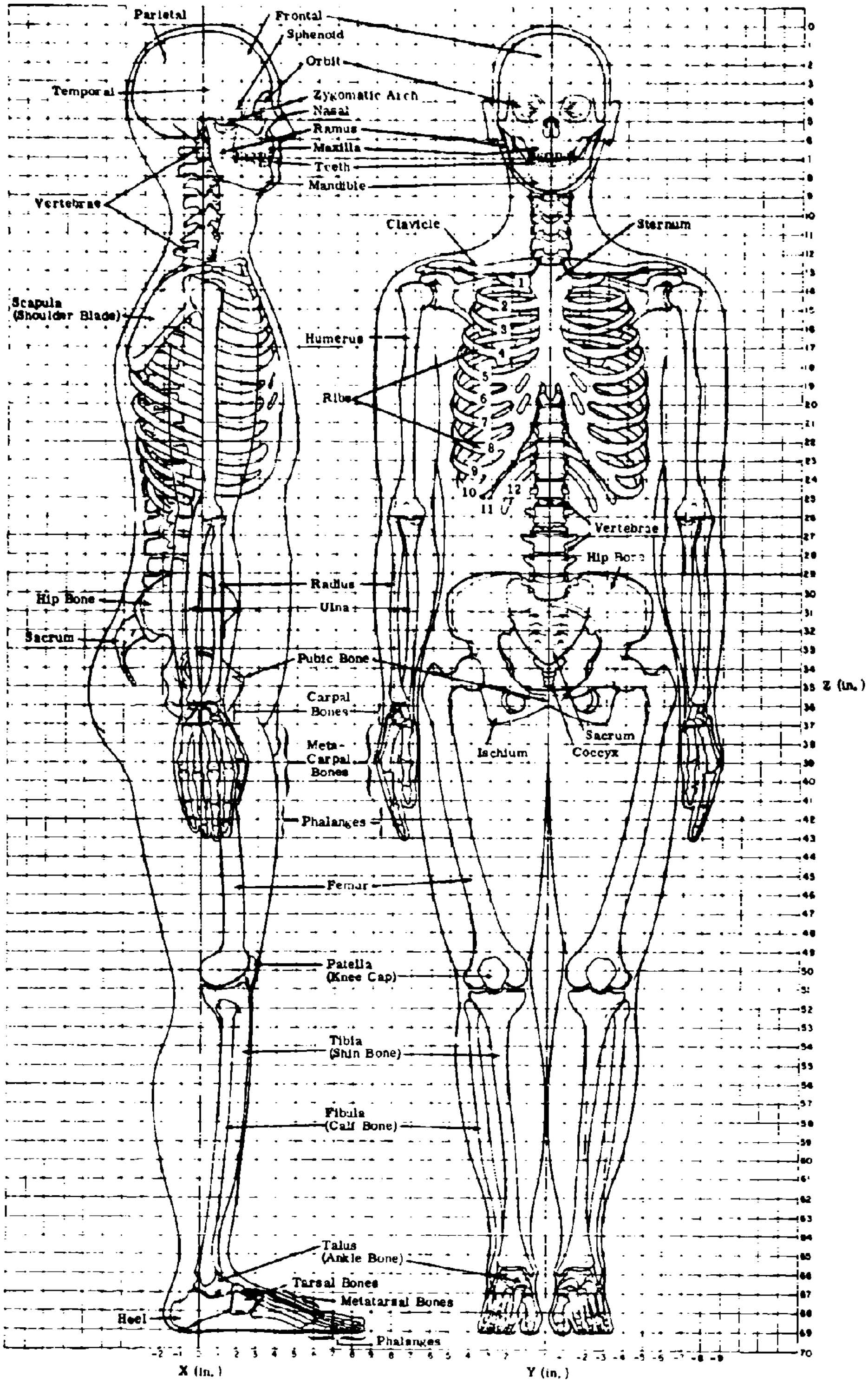


Figure 6 Skeleton Within Standing Man

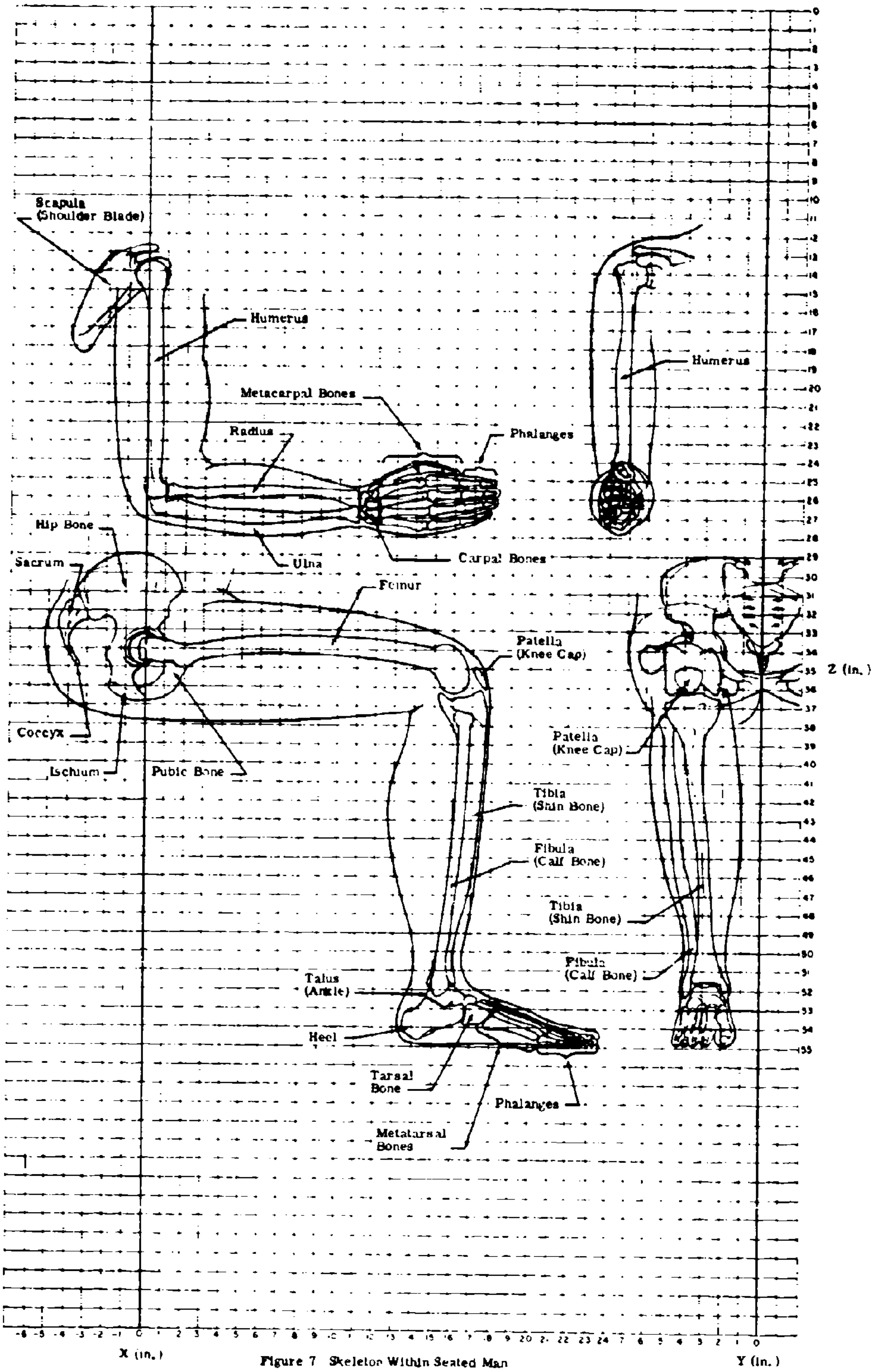


Figure 7 Skeleton Within Seated Man

d. Organs

The dimensional data available for organs was, as in the case of the skeleton, inadequate. Accordingly, the artist followed the same procedure used to develop the illustrations for the skeleton. In addition to the references cited for the skeleton, he also referred to Frohse(11) and Armstrong(12) during this phase. Another Clay Adams visual aid, the life-size model torso shown assembled in Figure 8 and disassembled in Figure 9, was borrowed for the preparation of these illustrations. The resulting layouts of the organs in the torso are shown in front and right side views on Figures 10 and 11, respectively. Views and sections of the individual organs are presented in Appendix I - Illustrations.

2. GEOMETRICAL REPRESENTATION

a. Input Required for the MEVDP

All geometrical data describing the Computerized Anatomical Model Man have been prepared in a punched card format compatible with the MEVDP. The punched card formats are explained in detail in Appendix II - Listing of Card Decks for Model. The types of geometrical shapes incorporated in MEVDP are shown in Figure 12. The number and symbols shown with the individual figures are locations, radii, and angles required by MEVDP. These shapes may be used individually as solids or may be combined in mixtures of up to 10 solids and voids to form composite shields. The voids are used only within composites to modify the shapes of the solids and thus to describe very complex shapes with a limited number of simple geometries. This capability was used extensively in the geometrical development of the model.

In addition to the geometrical data, the input to MEVDP includes the following:

- Shield identification;
- Shield type;
- Material identification;
- Material density;
- Number of shields within a composite.

Further explanation of all these inputs appears in Section III - Description of Model, and Appendix II - Listing of Card Decks for Model.

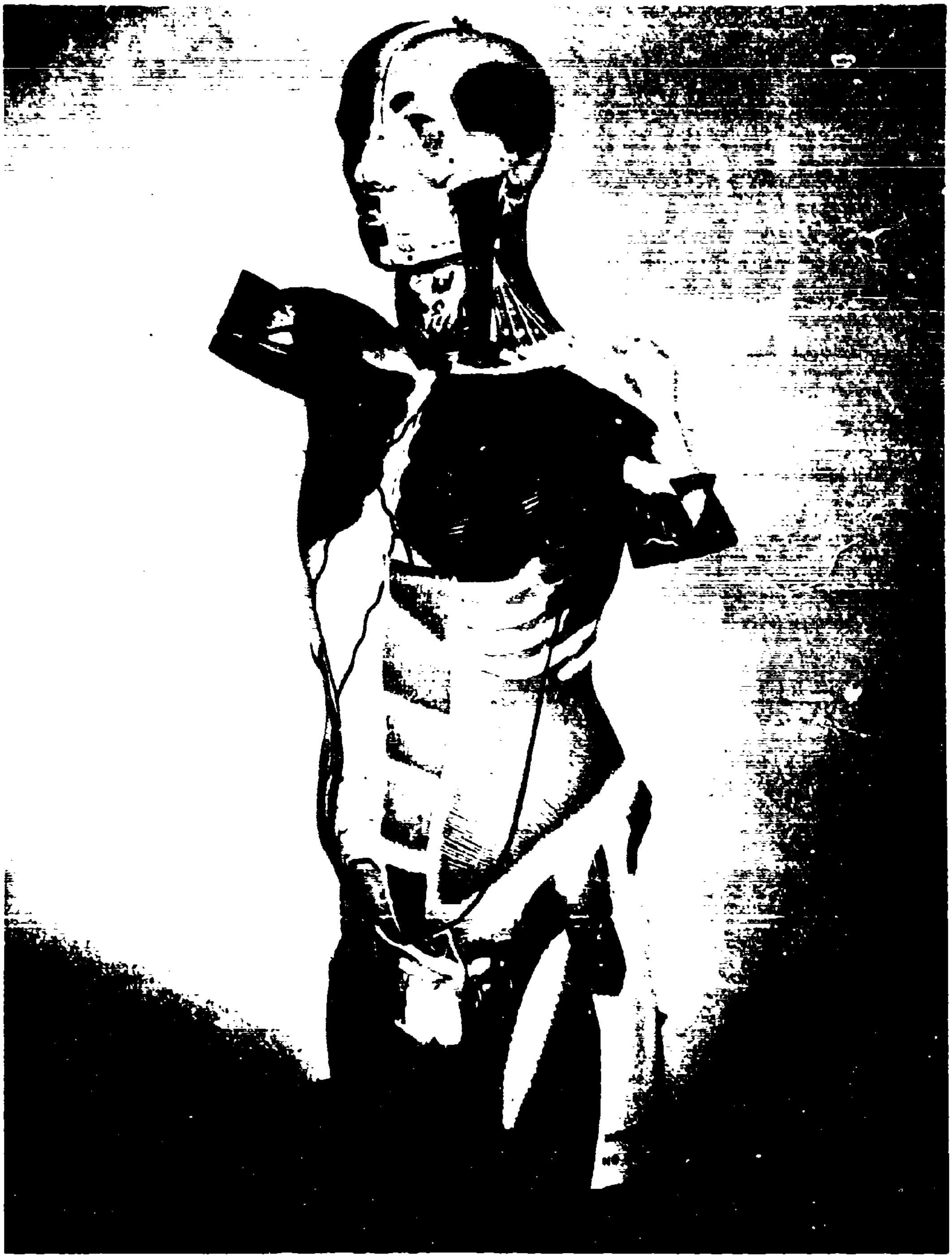


Figure 8 Plastic Model Torsc, Assembled

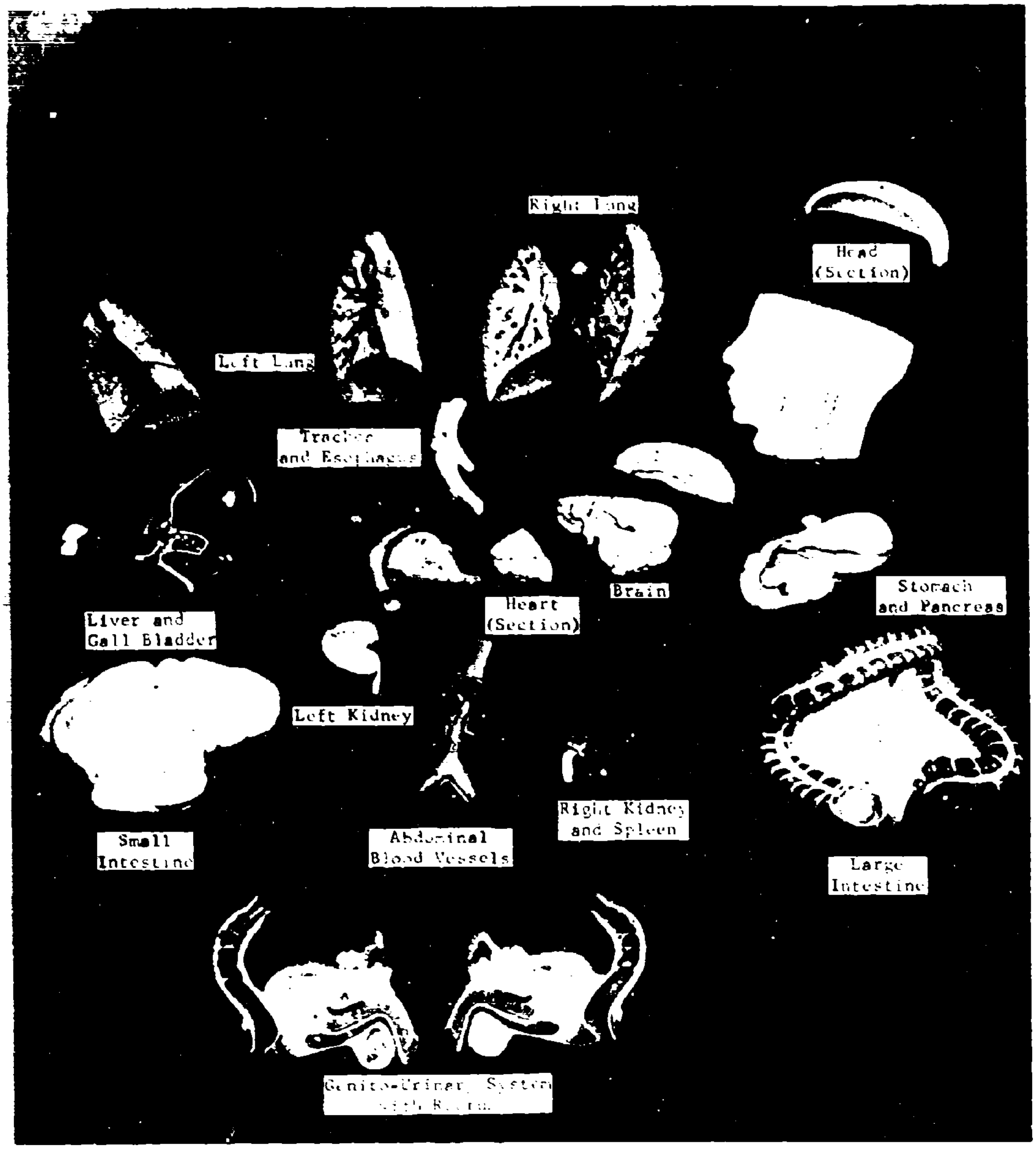


Figure 9 Plastic Model Torso, Disassembled

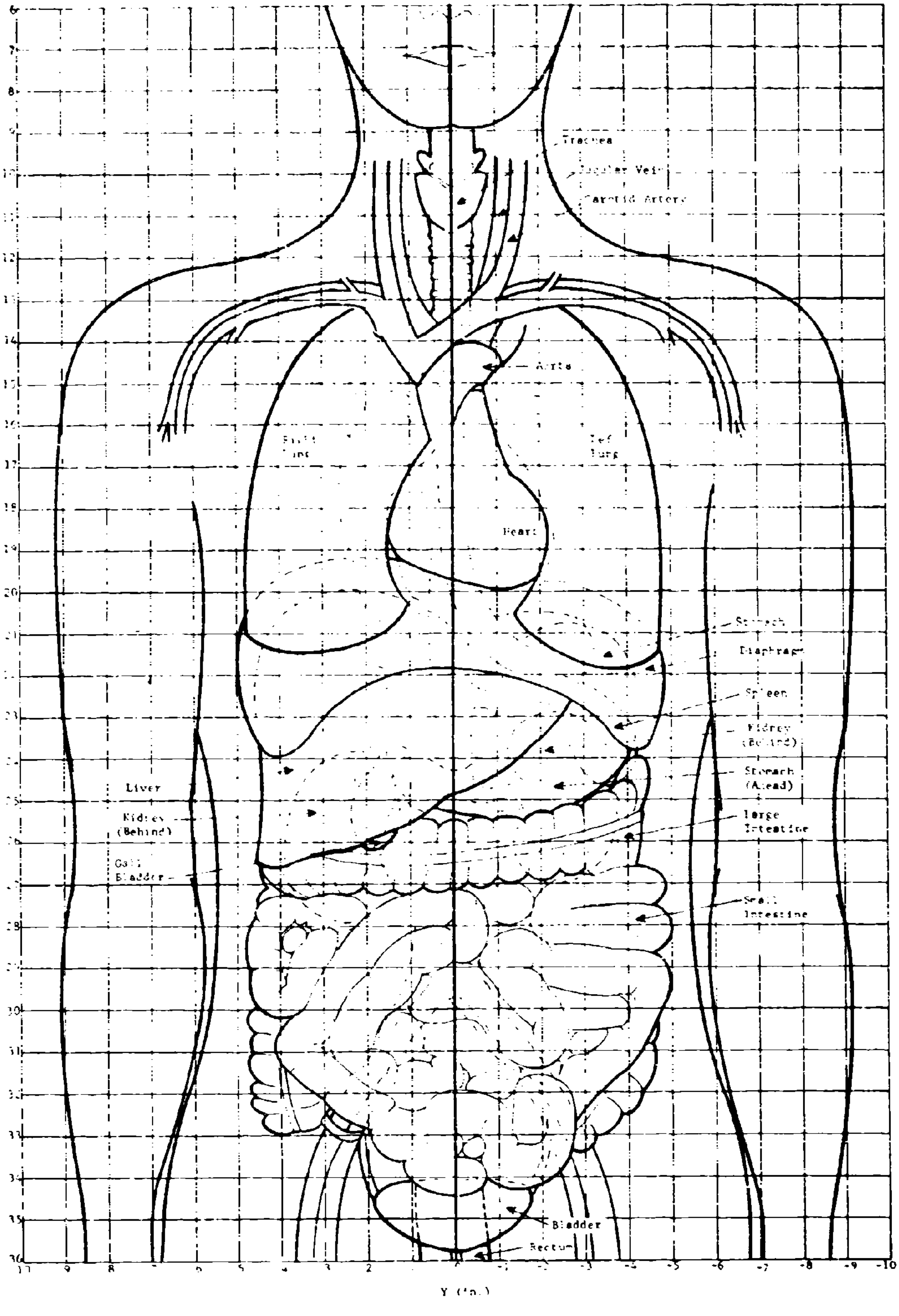


Figure [illegible]. Organs in Torso: Front View

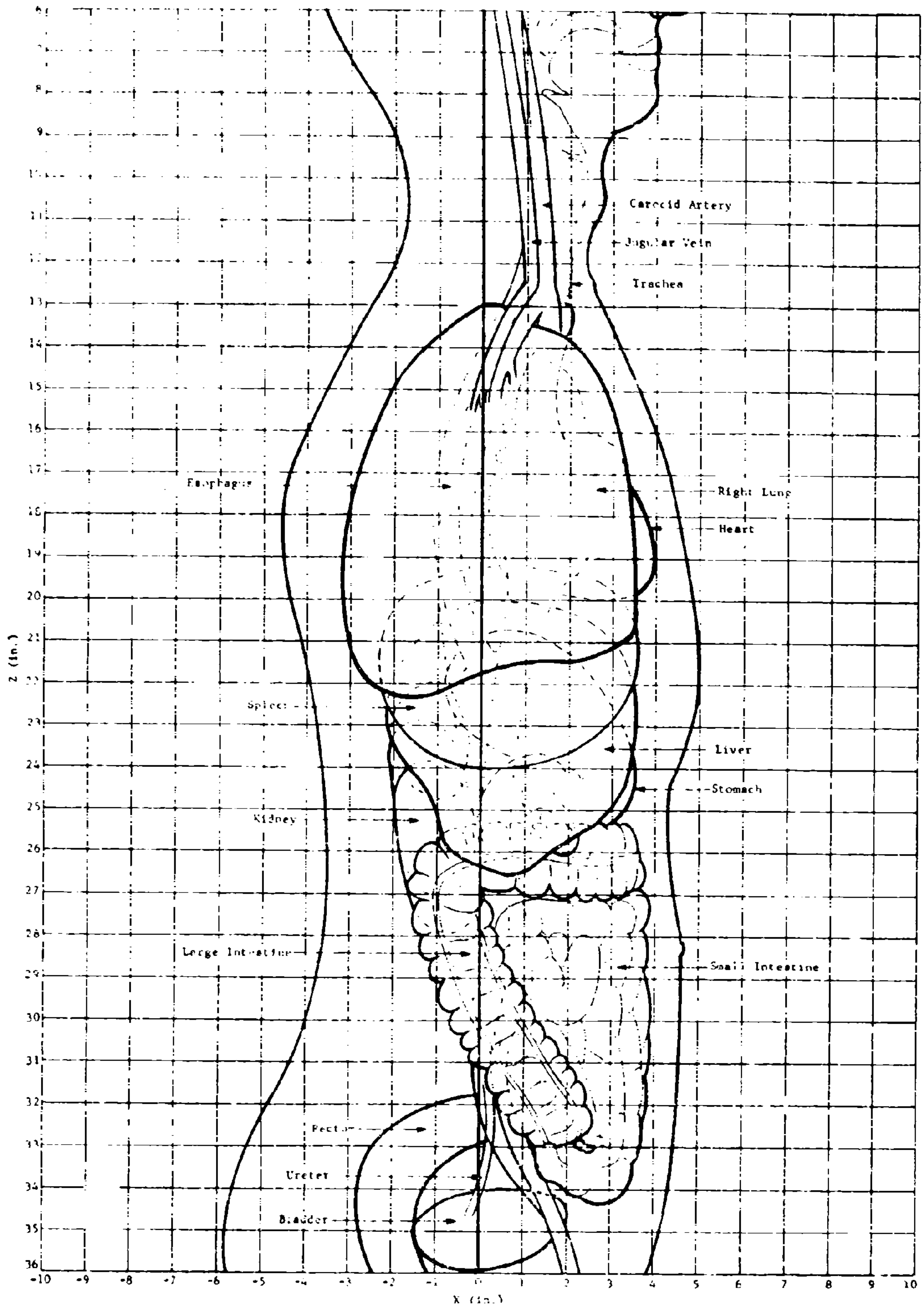
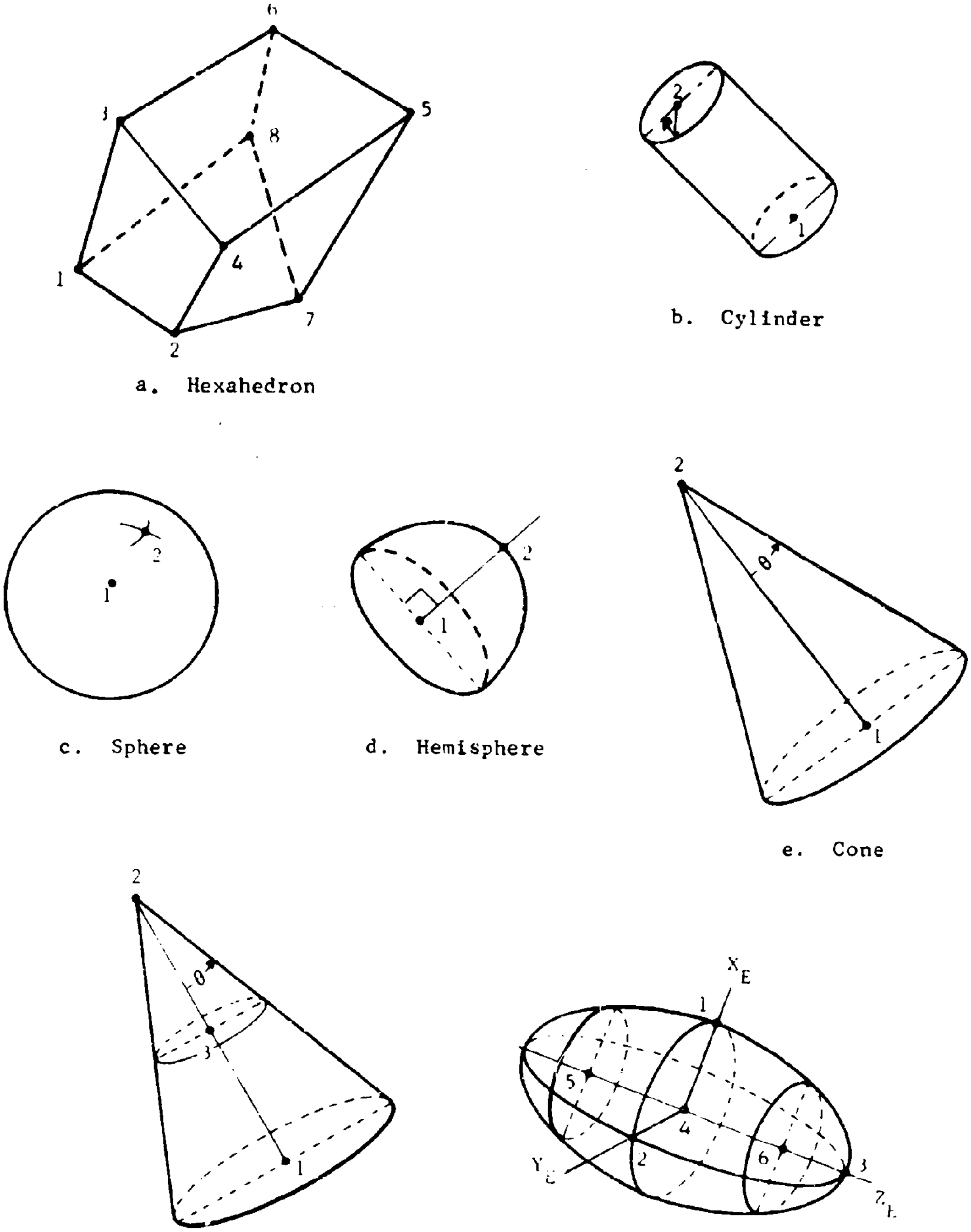


Figure [illegible]: Organs in Torso, Right Side View



a. Hexahedron

b. Cylinder

c. Sphere

d. Hemisphere

e. Cone

f. Truncated Cone

g. Ellipsoid

Figure 12 Geometrical Shapes Compatible with MEVDP

b. Design Procedure

Development of the geometrical representation entailed four steps. First, the external conformation was modeled. Next, the skeleton was designed independently of the exterior. Then, the skeleton and exterior were integrated. This procedure frequently involved modification of portions of both the exterior and the skeleton so that the combined shield configurations would be compatible with the allowable number of shields in a composite. As indicated earlier, MEVDP allows a mixture of 10 shields in a composite. However, the shield serial number system used in this study permits only 9 shields in a composite. (This number system is described in Section III - Description of Model). The final step of the development was modeling of the organs. No modification was involved during this step because the organs naturally fit within previously designed cavities of the skeleton and abdomen.

Simplifications of the design were made in several places in the interest of developing a model of reasonable size. On the exterior, all hair was ignored. In the case of the skeleton, the skull was simplified by not modeling the nasal septum, the zygomatic arches (or cheekbones), the mastoid processes, or the inner ear. The rib cage was simplified by assuming that the entire structure is a thin shell. The outline of the rib cage is correct, but the region between the ribs is bone, not tissue. Generally, the organs have their proper shape. However, the chest and abdominal cavities are completely filled with organ tissue. Fluids in which several organs float and supporting tissues and muscle have not been modeled. These simplifications are thought not to seriously affect the precision of the model, yet the number of shields in the model is several hundred fewer because of them.

The procedures in each step of the geometrical representation were identical. First, the geometric shapes forming the man were inferred by inspection of the illustrations the artist had made. Then, the numerical data required by MEVDP to define these geometries were read from the illustrations. This information was punched on data cards and also entered on Sectoring Code Worksheets, such as shown in Figure 13. These worksheets summarize all data requirements for MEVDP and were completed for the total of 3156 shields comprising the standing and seated versions of the model man.

02847

SECTORING CODE WORK SHEET

MDC - 06 - 8388 - C1 (3-69)

SHIELD SERIAL NUMBER		SHIELD TYPE	+ / —
MATERIAL CODE NUMBER		CHEMICAL COMPOSITION	
OCTANT NUMBER		DENSITY (GM CM3)	
CYL RADIUS (IN) OR CONE HALF ANGLE (RAD)			

			X (IN)	Y (IN)	Z (IN)
	SPHERE (2)	1			
	HEMISPHERE (2)				
	CYLINDER (2)	2			
	CONE (2)				
	TRUNCATED CONE (3) (TRUNCATION PT.)	3			
	SIMPLE ELLIPSOID (4)	4			
	TRUNCATED ELLIPSOID (5 OR 6) (TRUNCATION PT.)	5			
		6			
	HEXAHEDRON (8)	7			
		8			

REMARKS:

Figure 13 Example of Sectoring Code Worksheet

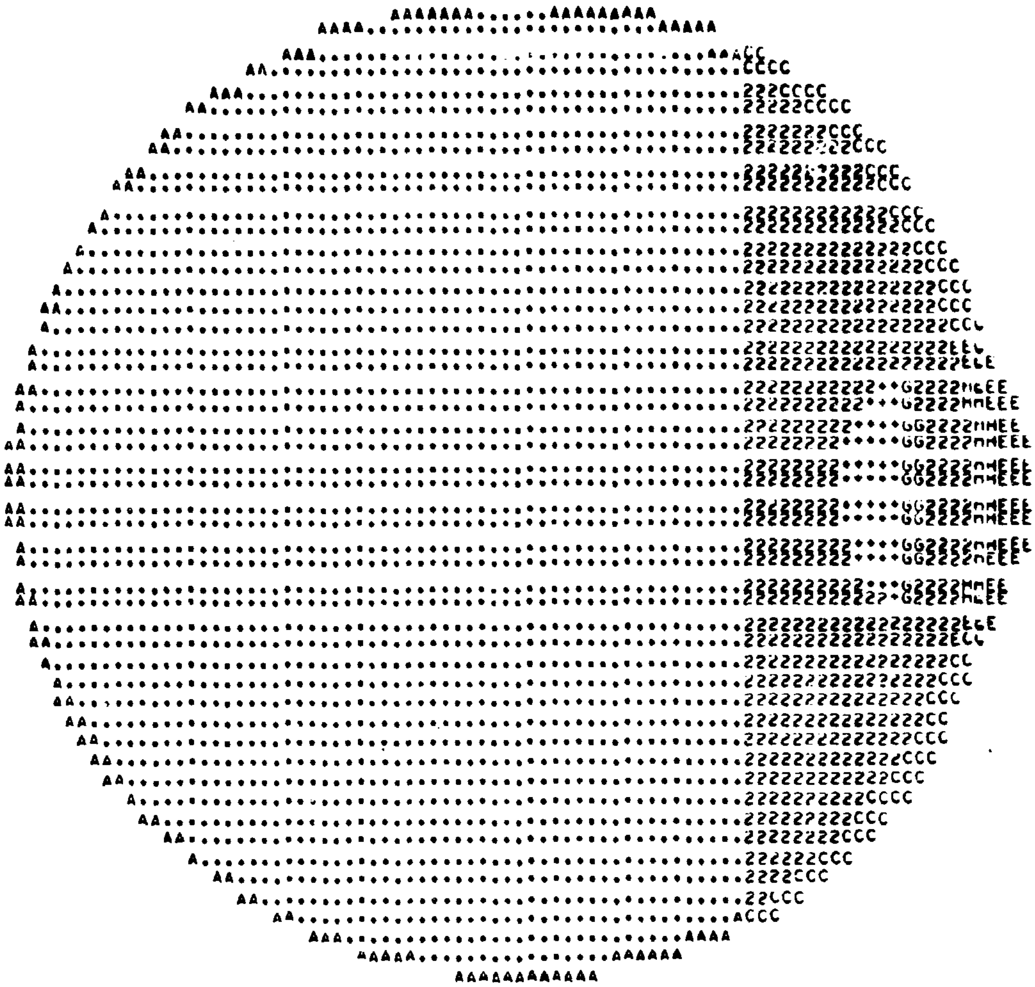
The model was checked by inspection of the card decks, matching of the data on the worksheets to both the illustrations and to the punched cards, and with two computer graphics programs. A version of MEVDP used by NASA Manned Spacecraft Center, Houston with the UNIVAC 1108 digital computer, has a CRT plotting routine that allows visual checking of the shielding geometry. Unfortunately, this version is incompatible with the Martin Marietta CDC 6500 digital computer. Therefore, the model was first checked in-house using the Lockheed LSVDC-4 Geometry Test Program to eliminate the obvious errors. Figure 14 is a drawing of the eye made by this program. The final visual checking of the model was done at the NASA Manned Spacecraft Center with MEVDP. Figure 15 is also the eye, but drawn by means of the MEVDP. Due to the intensive in-house checking prior to the final checks at NASA, only a few corrections were necessary.

3. CHEMICAL COMPOSITION AND DENSITY

a. Collection of Information

The penetration of radiation incident on the body to a dose point within is affected by both the chemical composition and the density of all intervening materials. A precise radiation transport model of man should therefore account for variations of these properties in skin, muscle, bone, bone marrow, fat, and the various organ tissues. The medical consultants were assigned the task of collecting and organizing information on the density of human tissues, and their fractional composition by weight of the principal chemical elements. The consultants reviewed the documents suggested by the government furnished bibliography and Long(9), Spector(10), Altman(13), and Glasser(14), as well. Of these sources, Long was most complete.

Unfortunately all of the chemical composition data examined during the study was inadequate for radiation transport analysis. In every case, the portions by chemical element did not total 100%. The better information accounted for only 70 to 80% of the constituents. The difficulty is related to the manner in which the information is obtained and documented. Frequently, the data is for dry tissue with no indication of how much water might have been present. In other cases, water content is shown, but the remainder is described as ash of undefined composition. In addition, there is no indication of how the ash was obtained or what chemical processes might have occurred during reduction of the tissue to ash. As a consequence, the losses of carbon, oxygen, and nitrogen could not be established.



Symbol Table	Material No.	Density (gm/cm^3)	Volume	Name
A	3	1.058	7	Aft Sclera
•	3	1.058	3	Aft Vitreous Humor
C	3	1.058	8	Forward Sclera
2	3	1.058	4	Forward Vitreous Humor
E	3	1.058	6	Cornea
+	3	1.058	2	Aft Lens
G	3	1.058	1	Forward Lens
H	3	1.058	5	Forward Aqueous Humor

Figure 14 Lockheed LSVDC-4 Computer Drawing of the Eye

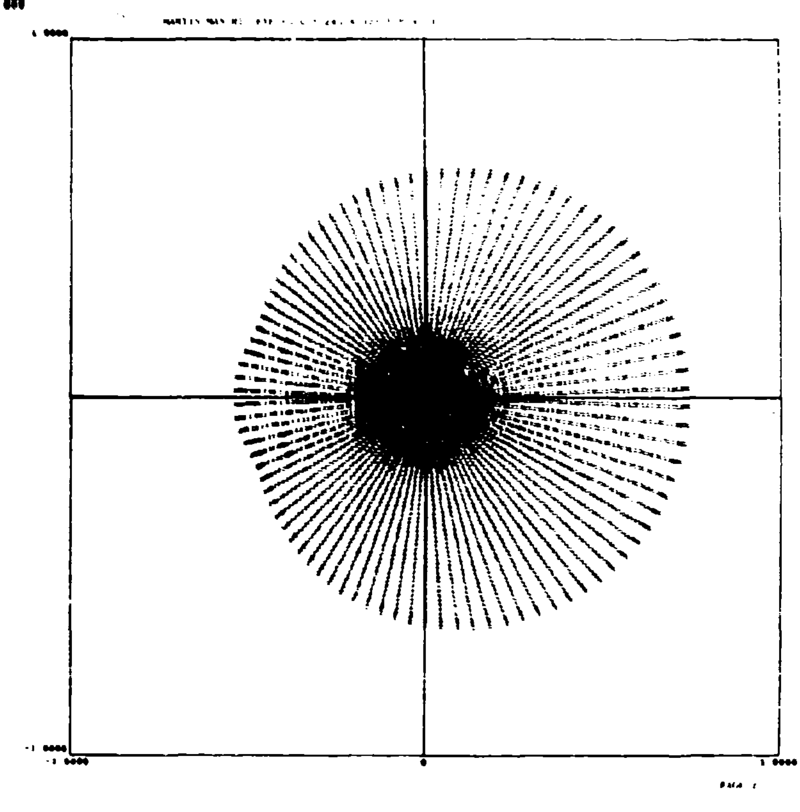


Figure 15 MEVDP Computer Drawing of the Eye

Because of these and other inadequacies in the chemical composition data, it was necessary to use approximations for the composition and density of organ and skeleton tissues. However, the geometrical models are complete. Improved data for chemical composition and density may readily be substituted in the future.

b. Organ Tissue

The medical consultants have formulated the radiation transport properties of a typical soft organ from the information gathered during the study. The typical density is that of blood, 1.058 gm/cm^3. The chemical composition is as follows:

Hydrogen	0.0980	Phosphorous	0.0030
Carbon	0.1450	Sulfur	0.0018
Nitrogen	0.0380	Potassium	0.0026
Oxygen	0.7070	Calcium	0.0009
Sodium	0.0015	Chlorine	0.0020
Magnesium	0.0002	Total	1.0000

These properties are used in all organs of this model.

e. Skeleton

Red blood cells are produced in the red marrow of the skeleton. Radiation reaching the blood formation centers could disrupt this production. Accordingly, the medical consultants have identified the distribution of red marrow in the human skeleton. This information is presented in Table II. The composition of bone marrow is similar to fat.

In order to plan the geometrical representation of the blood forming organs in the model, several of the larger human bones shown in Figure 5 were sawed into longitudinal and transverse sections. The artist illustrated these sections as shown by Figure 16. It is observed that the human bone is a very efficient shell structure reinforced internally with spongy material. As a consequence, the hard, dense material is concentrated in a very thin layer on the outside of the bone and the bulk of the interior is marrow. Description of the bone geometry separately from the marrow geometry would have added several hundred shields to an already large model. It was therefore decided that the radiation transport properties of the skeleton would be simulated adequately by combining the compositions and densities of bone and bone marrow, thus making a simpler geometric representation.

Table II. Distribution of Marrow in the Adult Human Skeleton

A. Distribution of Total Marrow, Red and Yellow, in Man. Total Marrow is 1600 to 3700 grams (3.53 to 8.15 lb), or 3.4 to 5.9% Body Weight.

Region/bones	Percent of Total	Subtotal	Total
Upper Limbs:			
Humeri	5.98		
Ulnae	1.38		
Radii	1.34		
Wrists and hands	2.74	11.44	
Lower Limbs:			
Femorae	17.07		
Tibiae	10.93		
Fibulae	1.54		
Patellae	0.82		
Ankles and feet	8.43	38.79	
Ribs and Trunk:			
1-4 ribs	2.08		
5-8 ribs	3.36		
9-12 ribs	1.90		
Scapulae	2.38		
Clavicles	0.76		
Sternum	1.38		
Pelvis	16.29	28.15	
Spinal Column			
Cervical vertebrae	1.78		
Dorsal vertebrae	7.29		
Lumbar vertabrae	5.61	14.68	
Skull			
Cranium	6.34		
Mandible	0.60	6.94	100.00

B. Distribution of Red Marrow (Blood Cell Producing). Red Marrow is 50% of Total in a 40 Year Old Male.

Bone	Percent of red marrow	Average weight (gm)	Total weight (gm)
Skull - cranium and mandible	13.1	136.6	
Humeri, scapulae, clavicles	8.3	86.7	
Sternum	2.2	23.4	
Ribs	7.9	82.6	
Vertebrae	28.5	297.8	
Pelvis	40.0	418.6	1045.7

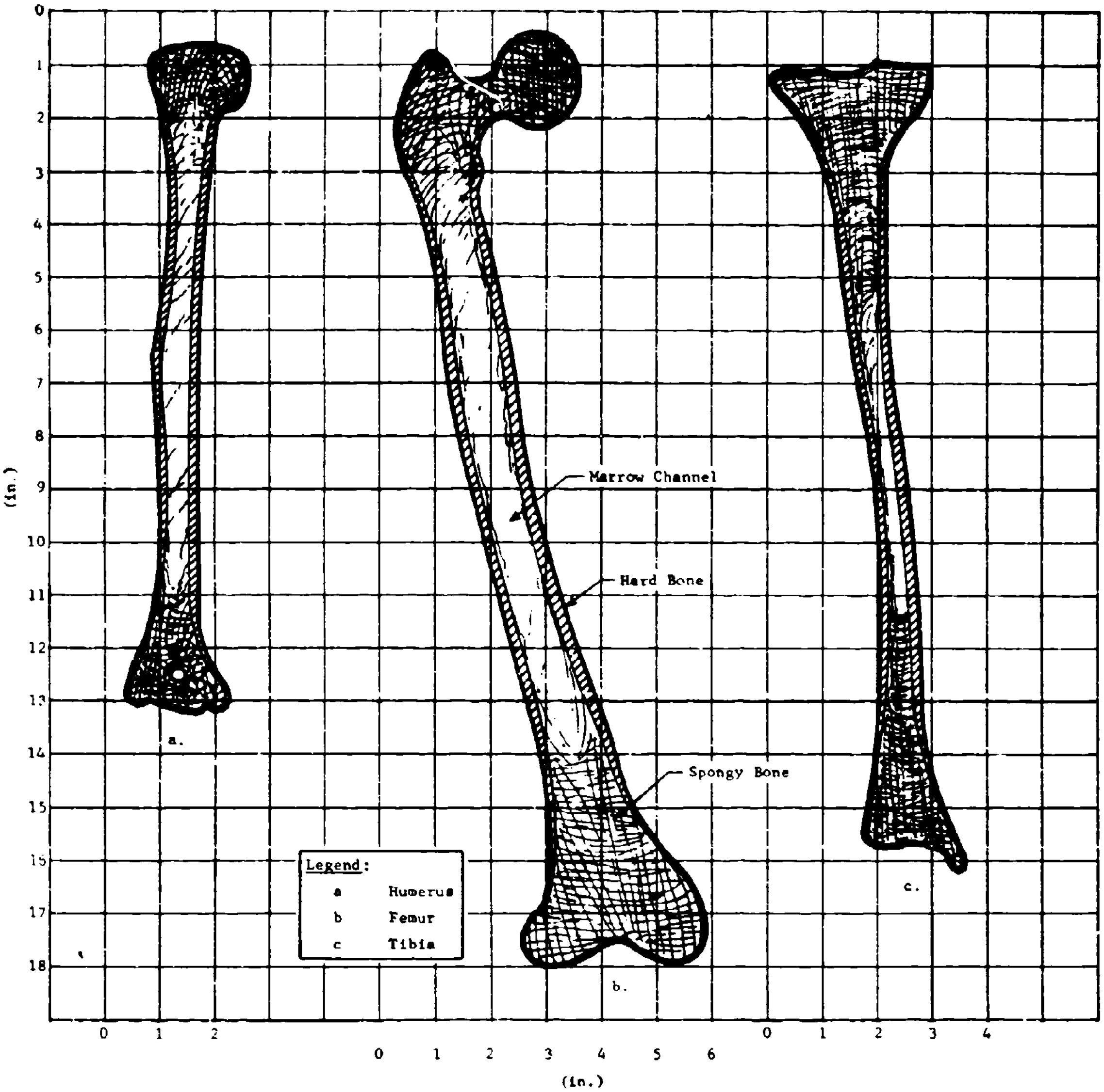


Figure 16 Sections of Human Bones

The properties of skeleton material were derived analytically using the following procedure. First, the geometrical model of the skeleton was developed by reference to the illustrations that had been prepared by the artist. The volume of this model was calculated next. Long[9] and Morgan[15] assign a total weight of 10 kilograms (22.046 lb) to the skeleton. Applying a calculated skeleton volume of 407.15 cu. in., the average density of the skeleton is 1.499 gm/cm^3. The density of bone is 1.75 gm/cm^3, that of marrow, 0.918 gm/cm^3, according to Long[9] and Spector[10]. Their distribution in the skeleton is given by Long[9] as 70% and 30%, respectively. The composition of bone according to Berger[16] is as follows:

Chemical Element		Fraction by Weight
Hydrogen		0.064
Carbon		0.278
Nitrogen		0.027
Oxygen		0.410
Magnesium		0.002
Phosphorous		0.070
Sulfur		0.002
Calcium		0.147
	Total	1.000

The chemical composition of bone marrow according to Dr. Gatts, one of our medical consultants, is as follows:

Chemical Element		Fraction by Weight
Hydrogen		0.122
Carbon		0.761
Oxygen		0.117
	Total	1.000

The calculated fractions by weight of bone and marrow in the skeleton were applied to these compositions to derive the following average composition of the skeleton;

Chemical Element		Fraction by Weight
Hydrogen		0.082
Carbon		0.423
Nitrogen		0.019
Oxygen		0.322
Magnesium		0.001
Phosphorous		0.049
Sulfur		0.001
Calcium		0.103
	Total	1.000

SECTION III

DESCRIPTION OF THE MODEL

1. SHIELD IDENTIFICATION AND LOCATION

A 4-digit number system has been used to identify and locate all geometrical shapes employed in the model. The digits are allocated as follows:

1st and 2nd - body segment;

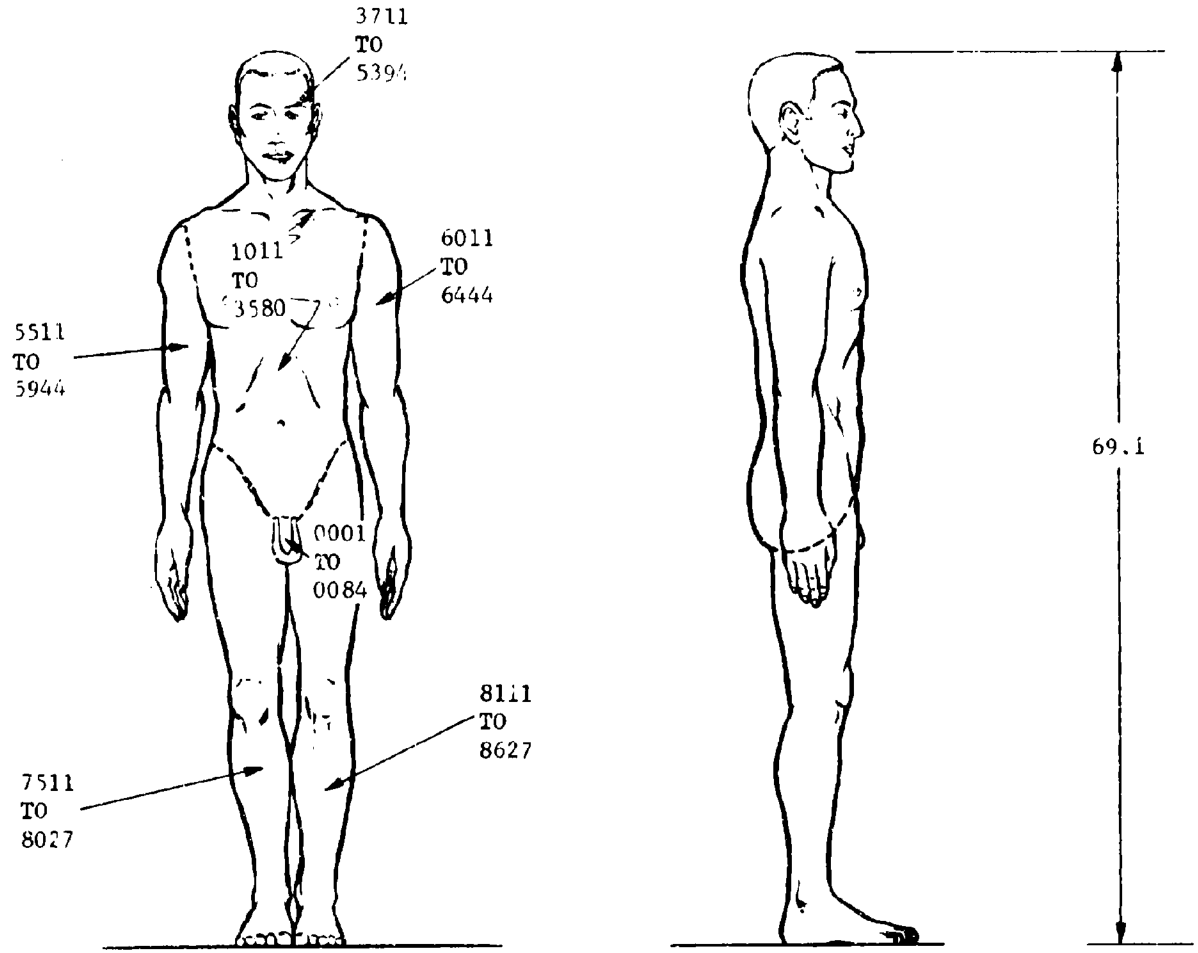
3rd - shield within the body segment;

4th - shield sequence within a composite shield.

If the shield is not a composite, the 4th digit is zero. Because of this rule, a composite may contain only 9 shields. Although a composite may contain more than one solid, if the solids do not overlap, it was convenient for the purposes of this study to allow only one solid shield in a composite. This simplified the weight analysis presented at the end of this section.

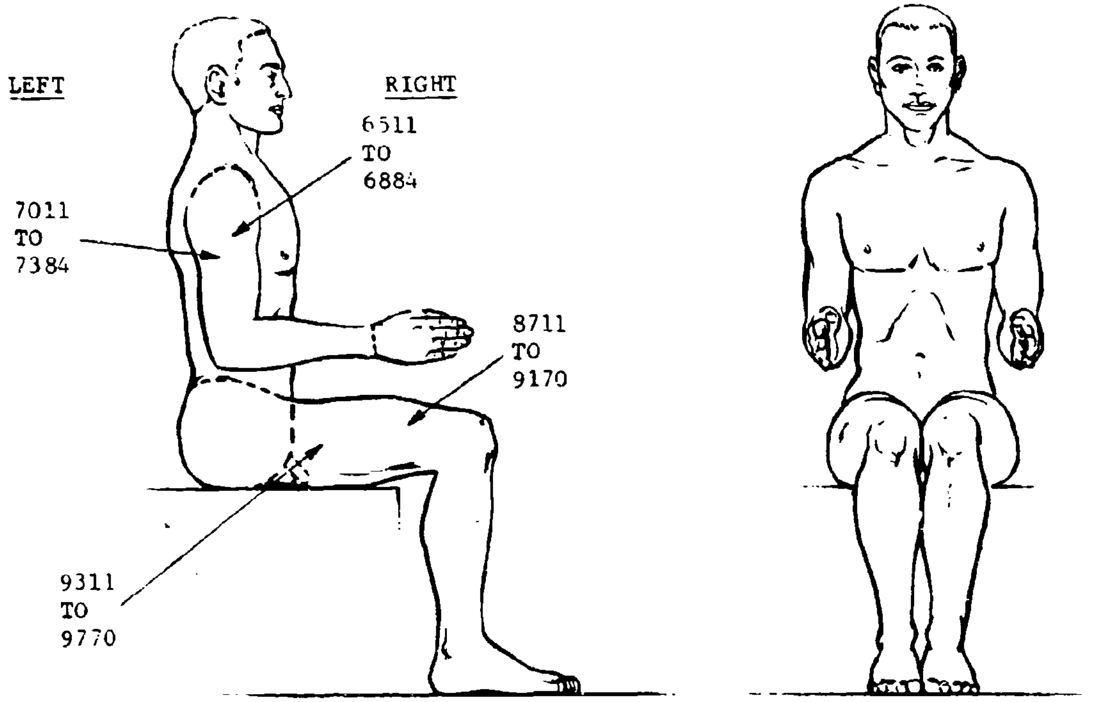
Groups of shield identification numbers have been assigned to the principal regions of the body. These assignments are shown in Figures 17 and 18 for the standing and seated positions, respectively. Within the body regions, the sequence is from back to front, right to left, and top to bottom. Also, major elements within the body region are sequenced in groups - muscle, skeleton, and organ. The distribution of shield identification numbers among body regions is summarized in Table III.

The locations of the composite shields of the model man both in the standing and seated positions are shown in Figures 19, 20, 21, and 22. The apportionment of muscle is shown on Figures 19 and 20; the composite shields of the skeleton are shown on Figures 21 and 22. The allocation of identification numbers to the individual organs is shown with the illustration of the organs in Appendix I - Illustrations.



Note: Dimensions in Inches.

Figure 17 Shield Identification Numbers Assigned to the Standing Man



Note: Segment numbering same as standing man except where noted.

Figure 18 Shield Identification Numbers Assigned to the Seated Man

Table III. Shield Identification Summary

Model Position	Body Region	Shield Identification Number Assignments			
		Entire Region	Muscle Tissue	Skeleton	Organs
Common to both standing & seated configurations	Torso	--	1011 to 2222	2721 to 3030	3150 to 3494
	Head	3711 to 5394	3711 to 4635	4641 to 5035	5041 to 5394
	Right Arm	--	5511 to 5526	5751 to 5780	--
	Left Arm	--	6011 to 6026	6251 to 6280	--
Unique to standing configuration	Genitals	0001 to 0084	0001 to 0084	--	(Incl in Torso)
	Torso	--	2231 to 2643	3041 to 3120	3511 to 3540
	Right Arm	--	5531 to 5740	5791 to 5944	--
	Left Arm	--	6031 to 6240	6291 to 6444	--
	Right Leg	7511 to 8027	7511 to 7748	7750 to 8027	--
	Left Leg	8111 to 8627	8111 to 8348	8350 to 8627	--
Unique to seated configuration	Genitals	--	--	--	(Incl in Torso)
	Torso	--	2651 to 2713	3131 to 3142	3551 to 3580
	Right Arm	6511 to 6884	6511 to 5730	5740 to 6884	--
	Left Arm	7011 to 7384	7011 to 7230	7240 to 7384	--
	Right Leg	8711 to 9170	8711 to 8938	8940 to 9170	--
	Left Leg	9311 to 9770	9311 to 9538	8540 to 9770	--

2. GEOMETRICAL SHAPES

The quantities of composite and individual shields employed in the Computerized Anatomical Model Man are summarized in Table IV. It is noted that there are 557 composite shields, representing 2518 individual geometrical shapes in the standing model and 504 composite shields representing 2271 individual geometrical shapes in the seated model. There are 336 composite shields and 1633 individual geometrical shapes common to both the standing and seated positions.

Of the seven geometries compatible with MEVDP, the ellipsoid is most useful for describing the human shape. The hexahedron was frequently used for creating cavities within other shapes or for truncating unwanted portions of the curved geometries. Of the other shapes, the truncated cone, the sphere, and the cylinder had varying, but considerably less, frequency of use. The hemisphere and the simple cone were never used in this model. The frequency of use of all shapes for the model man is summarized in Table V.

3. MATERIALS

Due to the difficulty experienced in gathering chemical composition data suitable for precise radiation transport calculations, the list of materials employed in the model is brief. Table VI shows the chemical compositions and densities assigned to the materials associated with this model. Of the ten materials shown, water and tissue, Morgan,[15] were not actually employed in the model. The data for these two materials are presented for comparative purposes.

It is noted that all of the tissues listed in Table VI have very high hydrogen and oxygen contents. It is well known that the specific gravity of the entire human body is very nearly equal to that of water. Applying the techniques of Berger,[16] it is seen in the following table that the principal radiation transport properties of water and all tissues except bone are similar.

Material	Atomic weight/atomic number	Adjusted mean excitation energy (electron volts)
Water	1.802	65.2
Tissue	1.904	65.7
Organ	1.825	66.7
Muscle	1.818	66.2
Bone	1.886	85.2
Bone Marrow	1.787	58.1
Skeleton	1.854	75.4

Table IV. Summary of Shields Employed in the Model Man

Body region	Composite shields	Individual geometrical shapes
Common to both standing and seated configurations:		
Head	153	772
Torso	171	803
Upper Limbs	12	58
Subtotal	336	1633
Unique to standing configuration:		
Genitals	9	27
Torso	50	284
Upper limbs	68	200
Lower limbs	94	374
Subtotal	221	885
Complete standing configuration	557	2518
Unique to seated configuration:		
Torso	12	62
Upper limbs	70	214
Lower limbs	86	362
Subtotal	168	638
Complete seated configuration	504	2271

Table V. Summary of Geometrical Shapes Employed in the Model Man

Body region	Hexahedron	Cylinder	Sphere	Truncated cone	Truncated ellipsoids		
					Not	Singly	Doubly
Common to both standing and seated configurations:							
Head	308	1	20	17	26	246	154
Torso	339	39	4	93	3	33	292
Upper Limbs	58	0	0	0	0	0	0
Subtotal	705	40	24	110	29	279	446
Unique to standing configuration:							
Genitals	7	0	0	0	7	4	9
Torso	43	54	6	70	2	23	86
Upper limbs	144	0	0	4	0	18	34
Lower limbs	306	0	0	12	12	18	26
Subtotal	500	54	6	86	21	63	155
Complete standing configuration	1205	94	30	196	50	342	601
Unique to seated configuration:							
Torso	32	0	6	0	2	9	13
Upper limbs	142	0	0	4	0	36	32
Lower limbs	278	0	0	8	28	18	30
Subtotal	452	0	6	12	30	63	75
Complete seated configuration	1157	40	30	122	59	342	521
Total utilization	1657	94	36	208	80	405	676

Table VI. Material Code Table

Chemical element	Fractional composition by weight									
	Code No.									
	1	2	3	4	5	6	7	8	9	10
	Name									
	Void	Lung	Organ	Intestine	Muscle	Bone	Marrow (fat)	Skeleton	Tissue	Water
	Density (gm/cm^3)									
	0.000	0.257	1.058	0.451	1.060	1.75	0.918	1.499	1.000	1.000
Hydrogen (H)		0.0980	0.0980	0.0980	0.1020	0.064	0.122	0.082	0.1000	0.1119
Carbon (C)		0.1450	0.1450	0.1450	0.1230	0.278	0.761	0.423	0.1600	---
Nitrogen (N)		0.0380	0.0380	0.0380	0.0350	0.027	---	0.019	0.0300	---
Oxygen (O)		0.7070	0.7070	0.7070	0.7290	0.410	0.117	0.322	0.6500	0.8881
Sodium (Na)		0.0015	0.0015	0.0015	0.0008	---		---	0.0015	
Magnesium (Mg)		0.0002	0.0002	0.0002	0.0002	0.002		0.001	0.0005	
Phosphorous (P)		0.0030	0.0030	0.0030	0.0020	0.070		0.049	0.0100	
Sulfur (S)		0.0018	0.0018	0.0018	0.0050	0.002		0.001	0.0025	
Potassium (K)		0.0026	0.0026	0.0026	0.0030	---		---	0.0020	
Calcium (Ca)		0.0009	0.0009	0.0009		0.147		0.103	0.0015	
Chlorine (Cl)		0.0020	0.0020	0.0020					0.0015	
Reference			Caranna		Berger[16]	Berger[16]	Gatts		Morgan[15]	

Because the skeleton is only about 14.3% of the adult body weight, only small errors should result from approximating the body with Morgan's version of an all tissue man. However, when better chemical composition and density data become available, the model may easily be updated for more precise analyses.

4. WEIGHT

One of the objectives of this study was to develop a model of the radiation transport properties of man that would weigh within 10% of the 50th percentile Air Force man. Since each of the two model configurations, standing and seated, is comprised of over 500 composite shields, representing over 2200 interacting geometrical shapes, it was necessary to automate the weight calculation. This was done by modification of MEVDP in the following manner.

MEVDP in its usual configuration divides space into a selected number of solid angles originating at the dose point. Then, rays are generated from the origin along the central axes of the solid angles. Whenever a ray intercepts an individual or a composite shield, the length of its track through the shield is calculated. These lengths are summed along each ray in terms of an equivalent material to form the areal density function used for dose calculations. To calculate weight, the same basic equations were used with different logic. First, in the cases of solid shields not in composites, the volumes and weights were calculated exactly with the standard formulas for the geometrical shapes compatible with MEVDP. In the cases where the shield element was a composite, a mock dose point was located at the center of the only solid shield assigned to the composite according to the rules adopted for this study. Then, the MEVDP equations were used to establish solid angles and rays at the dose point and to calculate the ray's track through the solid as modified by the voids included in the composite.

Simple modifications to the MEVDP provided the data for the following equation:

$$\Delta V_n = 1/3 \left(r_{2n}^3 - r_{1n}^3\right) \left(\varphi_{2n} - \varphi_{1n}\right) \left[\cos \theta_{1n} - \cos \theta_{2n}\right]$$

where

ΔV_n is the incremental volume associated with ray "n"

r_{2n} and r_{1n} are the distances from the dose point to the outer and inner surfaces, respectively, of the solid surface, as modified by adjoining voids

φ_{2n}, φ_{1n}, θ_{1n} and θ_{2n} are the angular limits of the solid angle element associated with ray "n" (Reference 4)

The volume of each composite was obtained by summing the incremental volumes over all rays. The weight was then the product of this volume and the density assigned to the composite. The mock dose point was relocated for each new composite. The preceding equation is exact for spheres and hemispheres and for ellipsoids whose semi-axes are allowed in the limit to become equal. As would be expected, the equation loses accuracy for shapes that are pointed or have corners, such as cones, cylinders and hexahedrons. Therefore, a study was made of the accuracy of the volume integration as a function of the number of rays selected for each type of geometrical shape for simple composites of one solid and one or more voids. The errors with respect to known, exact volumes are shown in Figure 23. Since the objective of the weight analysis was to reproduce the weight of the Air Force man within 10%, an error within a simple composite of 1% or less was considered satisfactory. Figure 23 indicates that 512 rays will limit the error to 1% in most cases.

Finally, a study was made of the effect of number of rays on the total volume of a group of composites and the time required to perform the calculation with the CDC 6500 digital computer. This analysis was done with the brain, which comprises 17 composites including a total of 59 geometrical shapes, mostly truncated ellipsoids. The results are shown in Figure 24. It would be expected that as the number of rays is increased, the volume would become asymptotic. This was generally true except for the sudden jog between 435 and 512 rays which was attributed to the solid angle distribution assuming a more favorable orientation with respect to the axes of the geometrical shapes in this region. As the result of this analysis, all volume and weight reported in this document are based on 512 rays. This number results in a volume little different from that obtained with many more rays and costs a reasonable amount in computation time.

The weight of the 50th percentile Air Force man is 161.9 pounds. The weight of the standing model man is 155.6 pounds. The seated model weighs 150.7 pounds. The errors in these weights are 3.9% and 6.9%, relative to the weight of the Air Force man. The calculated weights of the model man are summarized in Table VII. It is noted that the technique used to formulate the average chemical composition of the skeleton has forced its weight to be correct. The weights of individual organs are compared to weights of organs adapted from Morgan[15] and Sunderman[17] in Table VIII.

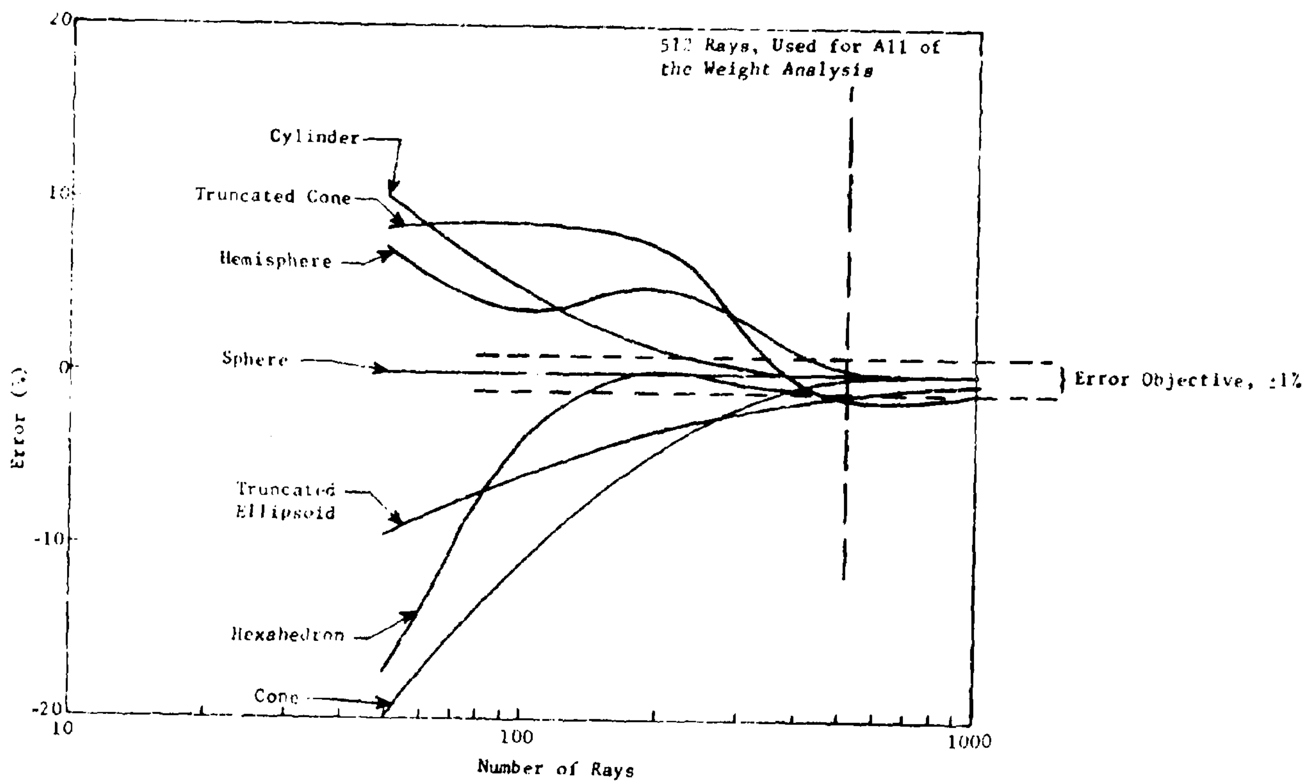


Figure 23 Errors of the Volume Calculation

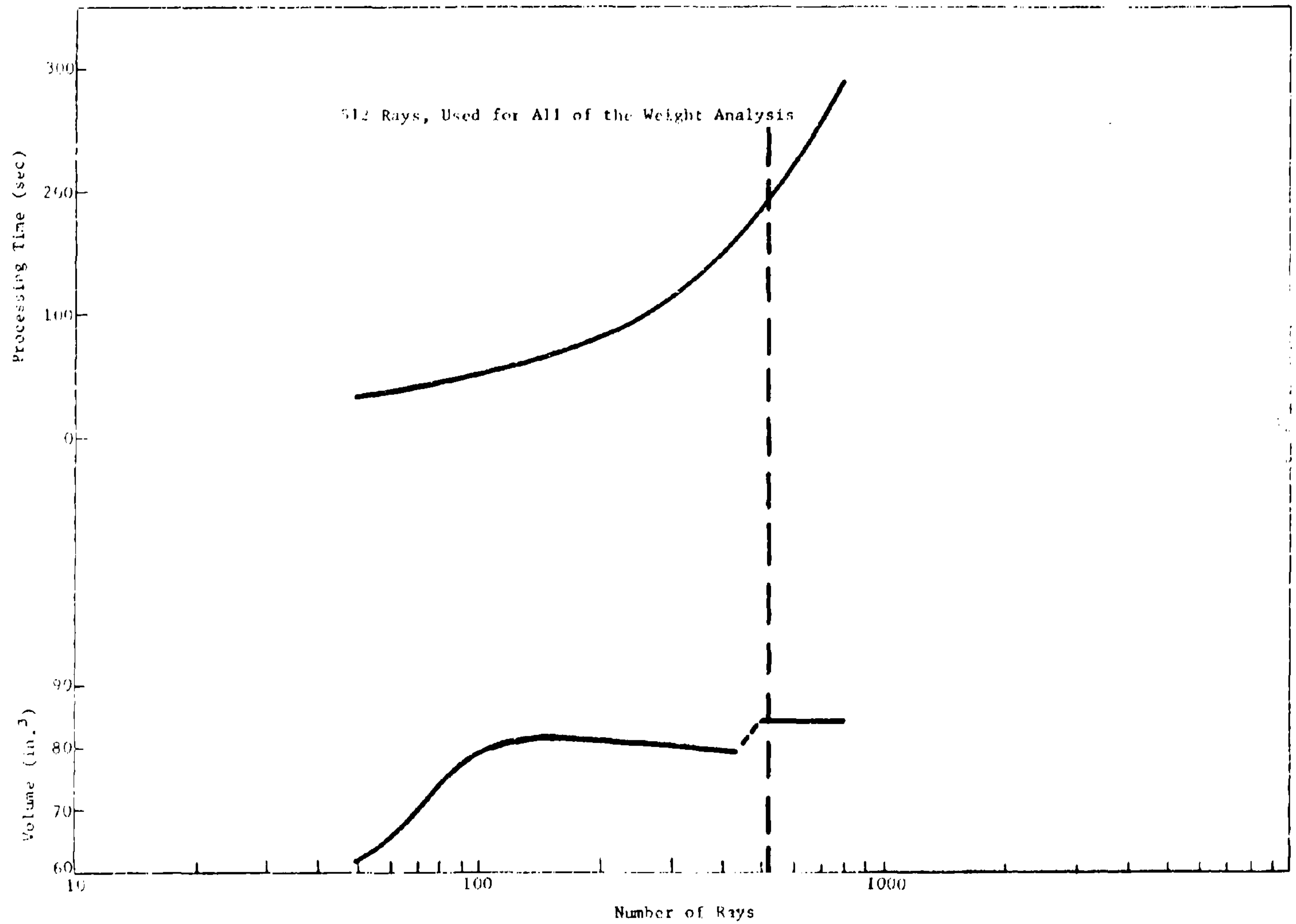


Figure 24 Time and Accuracy Analysis of the Brain Volume Calculation

Table VII. Summary of Model Man Weight

Body region	Tissue	Skeleton	Organ
Common to both standing and seated configurations:			
Head	4.5794	1.6986	2.6029
Torso	28.1042	11.4023	17.1606
Upper Limbs	0.7331	0.7629	---
Subtotal	33.4167	13.8638	19.7635
Unique to standing configuration:			
Genitals	0.2008	---	0.0832
Torso	17.6378	0.9590	1.5785
Upper limbs	15.8166	1.5300	---
Lower limbs	44.9349	5.6899	---
Subtotal	78.5901	8.1789	1.6617
Complete standing configuration:			
Total, each material	109.6839	22.0427	21.4252
Grand total	155.5530		
% error in grand total	3.92		
Unique to seated configuration:			
Genitals	---	---	0.0832
Torso	9.4900	0.2412	1.4915
Upper limbs	14.4615	1.5605	---
Lower limbs	49.5862	6.6231	---
Subtotal	73.5377	8.4248	1.5747
Complete seated configuration:			
Total, each material	104.6315	22.2886	21.3382
Grand total	150.6595		
% error in grand total	6.94		
Note: 50th percentile Air Force man weighs 161.9 lb.			

Table VIII. Comparison of Model and Actual Organ Weights.

Organs (weights in lb)	Model man (standing)	Morgan[15]	Sunderman[17]		
			Minimum	Maximum	Average
Eyes (both)	0.0834	0.0661			
Teeth	0.0123	0.0441			
Brain	2.5073	3.3069	2.4251	3.7479	3.0865
Spinal cord	0.2107	0.0661	---	---	0.0595
Thyroid	0.0279	0.0441	0.0661	0.1543	0.0882
Heart and adjoining vessels	3.3455	0.6614	0.5952	0.7937	0.6614
Lungs (both)	2.2046	2.2046	1.5102	2.3148	1.8188
Liver	2.9203	3.7479	3.3069	3.9683	3.6376
Spleen	0.2047	0.3307	---	---	0.3417
Kidneys and adrenal glands	1.1588	0.6614	0.5335	0.9964	0.7164
Bladder	0.4571	0.3307	---	---	---
Pancreas	0.2014	0.1543	0.1323	0.2976	0.2425
Stomach	1.1306	8.0138	---	---	---
Intestines	6.8775		---	---	---
Testicles (both)	0.0832	0.0882	0.0882	0.1190	0.1102
Total	21.4252	19.7203			

Note: Organs of the Model Man are assumed to be filled with blood, food, feces, or urine as appropriate.

Best Available Copy

It is noted that the weights of the model organs are generally somewhat greater than those given in the reference. Part of this discrepancy is attributed to the modeling technique. The organs were assumed to entirely fill the cavities in the skull, rib cage, and abdomen. Actually, this is not true because the organs are cushioned by fluids and supported by various tissues and muscles. These details were not modeled in the interest of keeping the number of geometrical shapes used in the model to a reasonable number. Another possible source of discrepancy between the weights of the model organs and actual organs may be due to preparation of the actual organs. The references do not indicate whether blood and other fluids normally within the living organs were drained prior to weighing. It is suspected that unless the donors were frozen immediately after death, the organs were drained. Since the model assumes the entire volume of the organ to be occupied by tissue and fluids having a uniform density equal to that of blood, it would be expected that the model organs should be heavier than organs without the normal fluid content they had while living.

SECTION IV

MODEL DEMONSTRATION

1. DOSE POINTS

Compatibility of the Computerized Anatomical Model Man with MEVDP was demonstrated by operation of the two systems together on the CDC 6600 digital computer at the Air Force Weapons Laboratory. In preparation for this demonstration, the locations of numerous dose points were identified. These locations are given in Table IX. It is noted that except for the gonads and femur the dose point locations are the same in the standing and seated configurations.

2. SAMPLE PROBLEMS

Demonstration of the model at the Air Force Weapons Laboratory entailed solution of shielding thickness problems for si.. dose points chosen from Table IX. Both standing and seated configurations were used. The model was input to MEVDP from both punched cards and magnetic tape. The demonstration conditions were as follows:

Problem no.	Dose point	Model configuration	Input source	No. of rays	Computer time (sec)
1	Heart	Seated	Tape	512	420.813
2	Intestines	Seated	Tape	512	445.660
3	Hypothalamus	Seated	Cards	512	502.227
4	Heart	Standing	Tape	512	430.500
5	Intestines	Seated	Tape	200	211.876
6	Hypothalamus	Standing	Cards	512	615.913

A partial listing of the result of problem number 1 is presented in Appendix III - Listing of Sample Problem Results.

Table IX. Dose Point Locations Within the Model Man

Dose point	Coordinates (in.)		
	X	Y	Z
Inner ear:			
Right, at drum	-0.03	2.04	5.00
Right, at cochlear nerve	-0.23	1.68	4.75
Hypothalamus at center of mass	0.90	0.00	4.10
Lungs at center of mass:			
Right	0.36	2.48	18.00
Left	0.36	-2.82	17.61
Heart at center of mass	1.71	0.14	17.60
Kidneys at center of mass:			
Right	-0.90	2.53	25.80
Left	-1.10	-2.53	24.65
Pancreas at center of mass	1.50	-0.81	24.45
Gonads at center of mass:			
Right testicle, standing	2.25	0.55	38.25
Left testicle, standing	2.25	-0.55	38.50
Right testicle, seated	4.74	0.55	36.84
Left testicle, seated	4.95	-0.55	36.97
Bone marrow channels:			
Sternum at center	3.26	0.00	15.62
Right femur at center, standing	1.60	4.33	43.38
Right femur at center, seated	9.13	4.33	33.80
Eyes:			
Right at center of lens	3.393	1.245	4.30
Right, retina at optic nerve	2.278	1.245	4.30
Intestines at center of mass	1.80	-0.20	28.95
Spleen at center of mass	-1.18	-3.37	23.4
Brain at center of mass	-0.30	0.00	3.43

Note: Ears and eyes are located symmetrically with respect to the XZ plane.

SECTION V

RESULTS AND RECOMMENDATIONS

1. SUMMARY OF RESULTS

This study has produced a Computerized Anatomical Model Man in both standing and seated configurations. The model depicts a 50th percentile Air Force man and comprises over 2200 geometrical shapes representing his external conformation, skeleton, and major organs. The quantity of geometrical shapes used in this model compares to 968 shapes used in an existing model of the Apollo Command and Service Module and 1038 in a model of the Apollo Lunar Module. Despite the number of geometrical shapes employed in this model, it was necessary to make compromises to achieve a model man of reasonable size yet sufficient geometrical accuracy.

Due to inadequacies in the data available to this study, the chemical compositions and densities assigned to the parts of the model do not represent the radiation transport properties of man precisely. However, since the greatest part of living human tissue is similar to water in both composition and density, these inadequacies may not be significant. The model is so constructed that better information may easily be substituted.

The compatibility of the Computerized Anatomical Model Man with an existing radiation shielding program, MEVDP, has been demonstrated. Since this computer program is operational at the Air Force Weapons Laboratory, the NASA Manned Spacecraft Center, Houston, North American Rockwell Corporation, and other government and industrial centers as well, the model should have considerable utilization.

2. RECOMMENDATIONS

Studies should be made using the model in one or several fixed environments to determine the sensitivity of doses calculated at various locations to the chemical composition and density of muscle tissue, skeleton, and organs. These doses should also be compared to doses calculated at the same locations using a uniform tissue composition such as that suggested by Morgan.[15] If it is discovered that important differences in the doses result, additional research into man's composition and density would be indicated to update this part of the model.

It is noted that the Computerized Anatomical Model Man is nude. Omitting clothing results in a conservative dose calculation. However, credit should be taken for a spacesuit in studies of extra-vehicular activity.

Some broadening of the geometrical capability of MEVDP would be desirable. If the cones, truncated cones, and cylinders had elliptical sections rather than circular sections they would be more useful. MEVDP uses only convex shapes, that is, all solid material is on the interior. Concave shapes, or the ability to use the exteriors of the convex shapes as voids, would also have been useful.

APPENDIX I

ILLUSTRATIONS

To facilitate the modeling of the 50th percentile Air Force man's exterior, skeleton, and organs, the artist prepared numerous sectional drawings of the entire man and views of individual organs and bones that are obscured in the complete drawings. These illustrations were used to infer the geometrical shapes that would best simulate the man.

The locations of the body sections are shown on Figures 3 and 25. The numerical scales on each drawing that follows locate the section in the main man coordinate system. Figures 26 through 31 show the location of the skeleton within the external conformation of the body. Views of the spinal column and pelvis are presented in Figures 32 and 33, respectively.

The remaining figures include front and right side views of the main organ systems -- nervous, circulatory, and gastrointestinal, views of individual organs, and sections of these organs. The locations of the organs are shown in Figures 10 and 11; the locations of organ sections are shown on the appropriate views. The composite identification numbers associated with these organs are also indicated as well as the shapes of the primary solid volumes of the composites. The effects of voids that in many cases cause large changes in the final appearance of the shield are not shown. The location of the eye in the head is shown in Figure 34. The dimensions of the eye in the model are based on Gullstrand's schematic eye as cited by Southall[18]. All other organ dimensions are the result of scaling the anatomical models to the dimensions of the 50th percentile Air Force man. The central nervous system -- brain and spinal cord, is shown in Figure 35; the thyroid in Figure 36. The main circulatory system is shown in right side and front views in Figure 37. Horizontal and vertical sections of the heart and adjoining blood vessels are shown in Figure 38. Figure 39 presents the nasal and oral passages of the head, the esophagus and the trachea. The lungs and their sections are shown in Figures 40 and 41. These organs are followed by the liver and gall bladder, in Figures 46 and 47; and the bladder, Figures 48 and 49. The gastrointestinal tract is shown in Figure 50. Views and sections of the pancreas appear in Figures 51 and 52. Finally sections of the stomach, small and large intestines are presented in Figure 53.

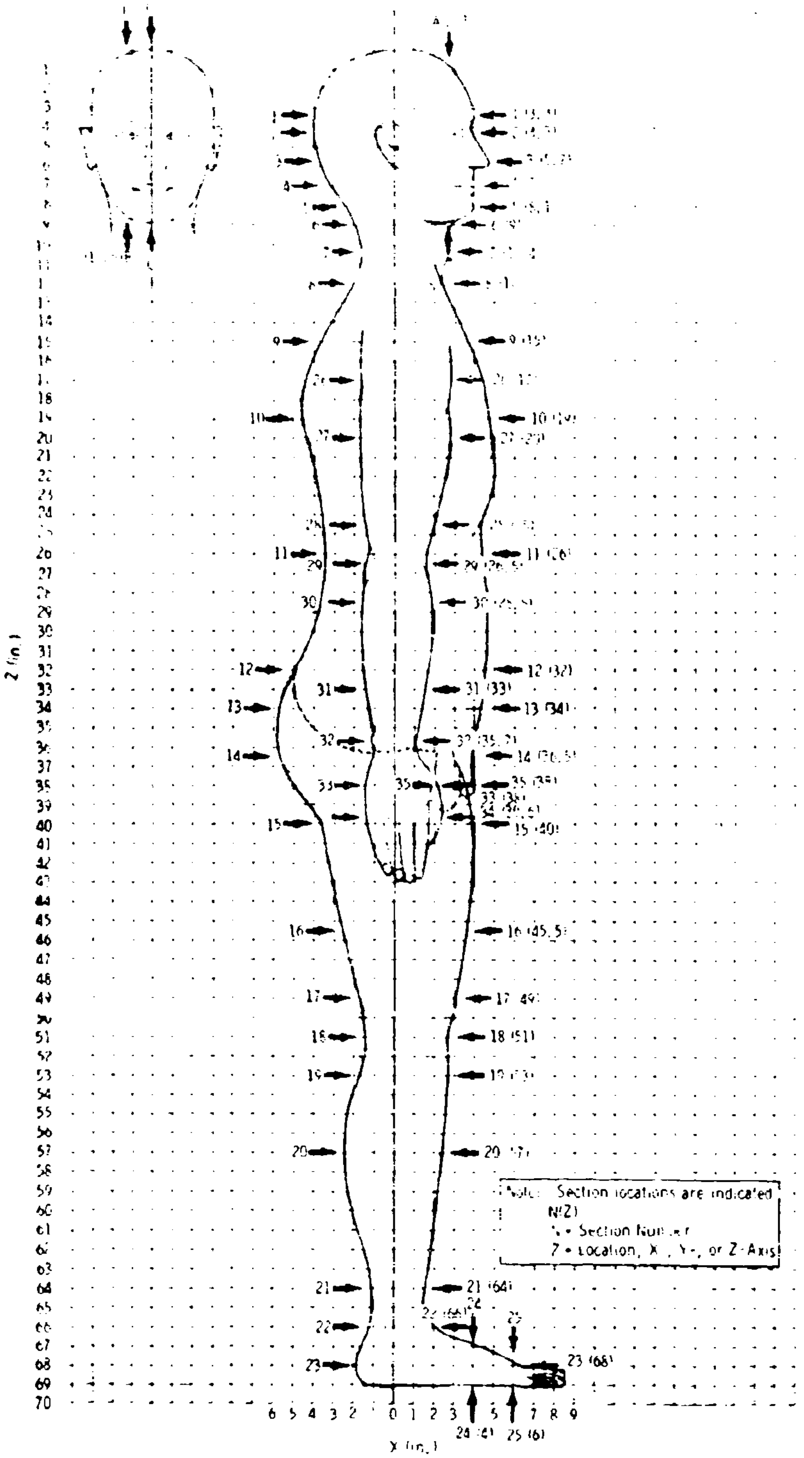


Figure 25. Locations of Body Sections

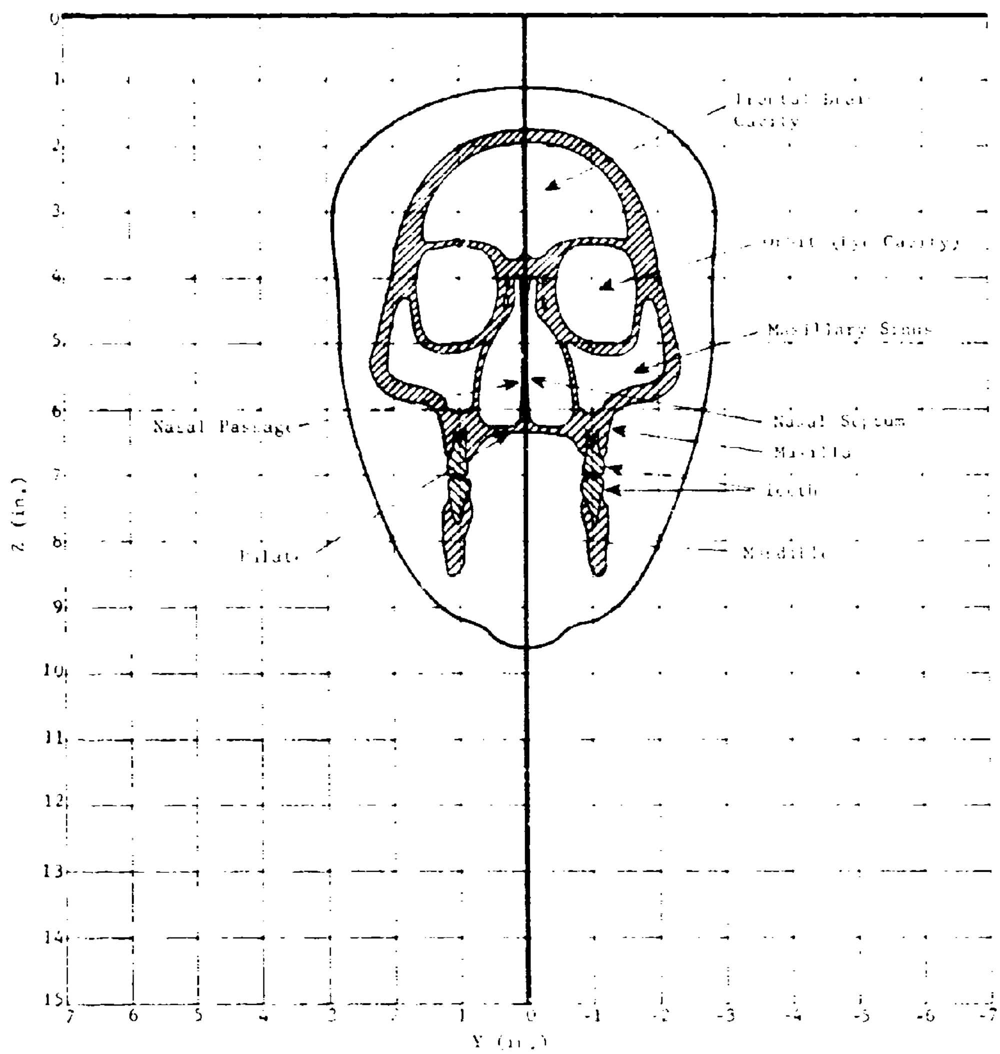


Figure 26 (A) Vertical Section of Head, Normal to X-Axis at X = 2.7 inches

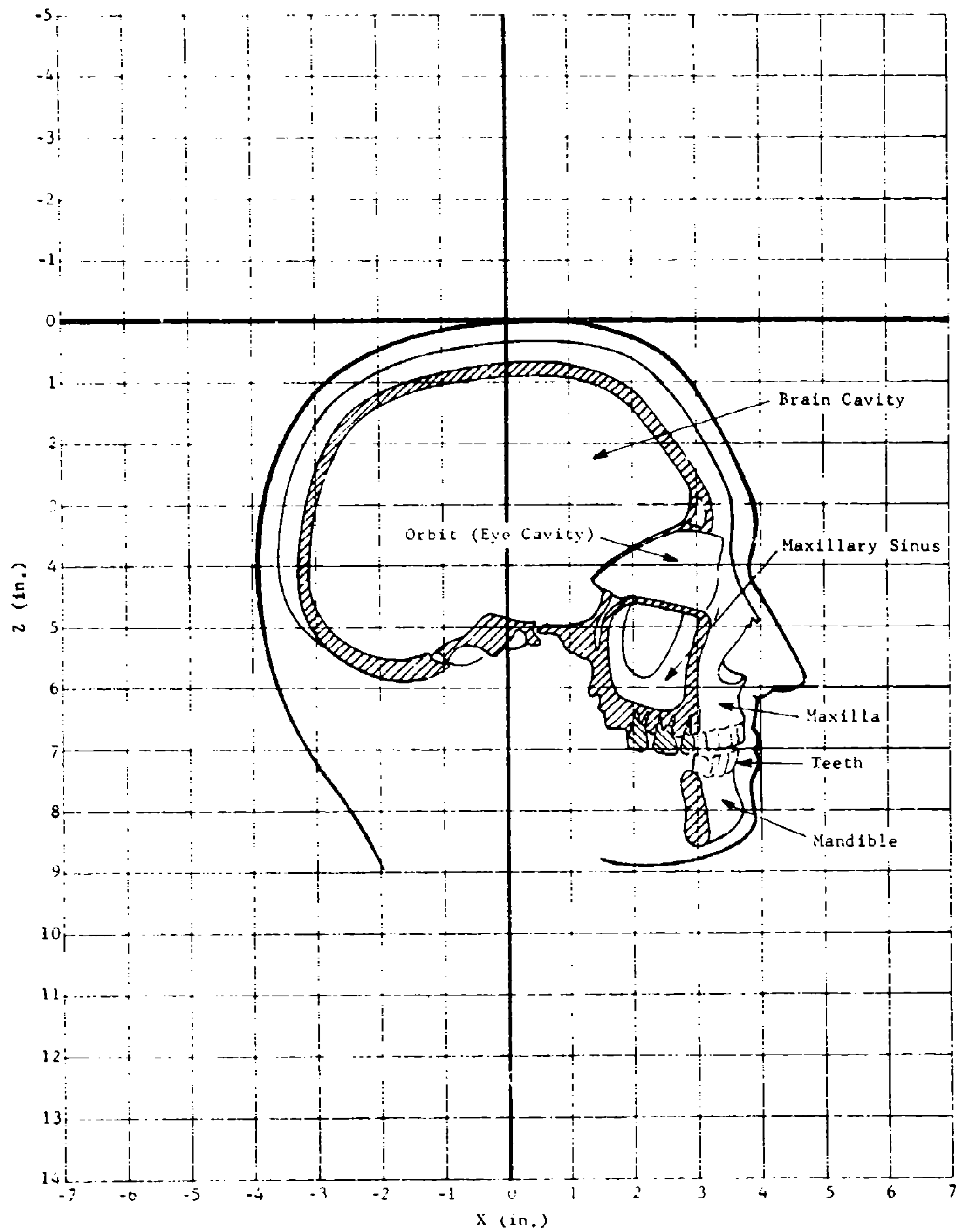


Figure 27 (B) Vertical Section of Head, Normal to Y-Axis at Eye Pupil Y = 1.25 inches

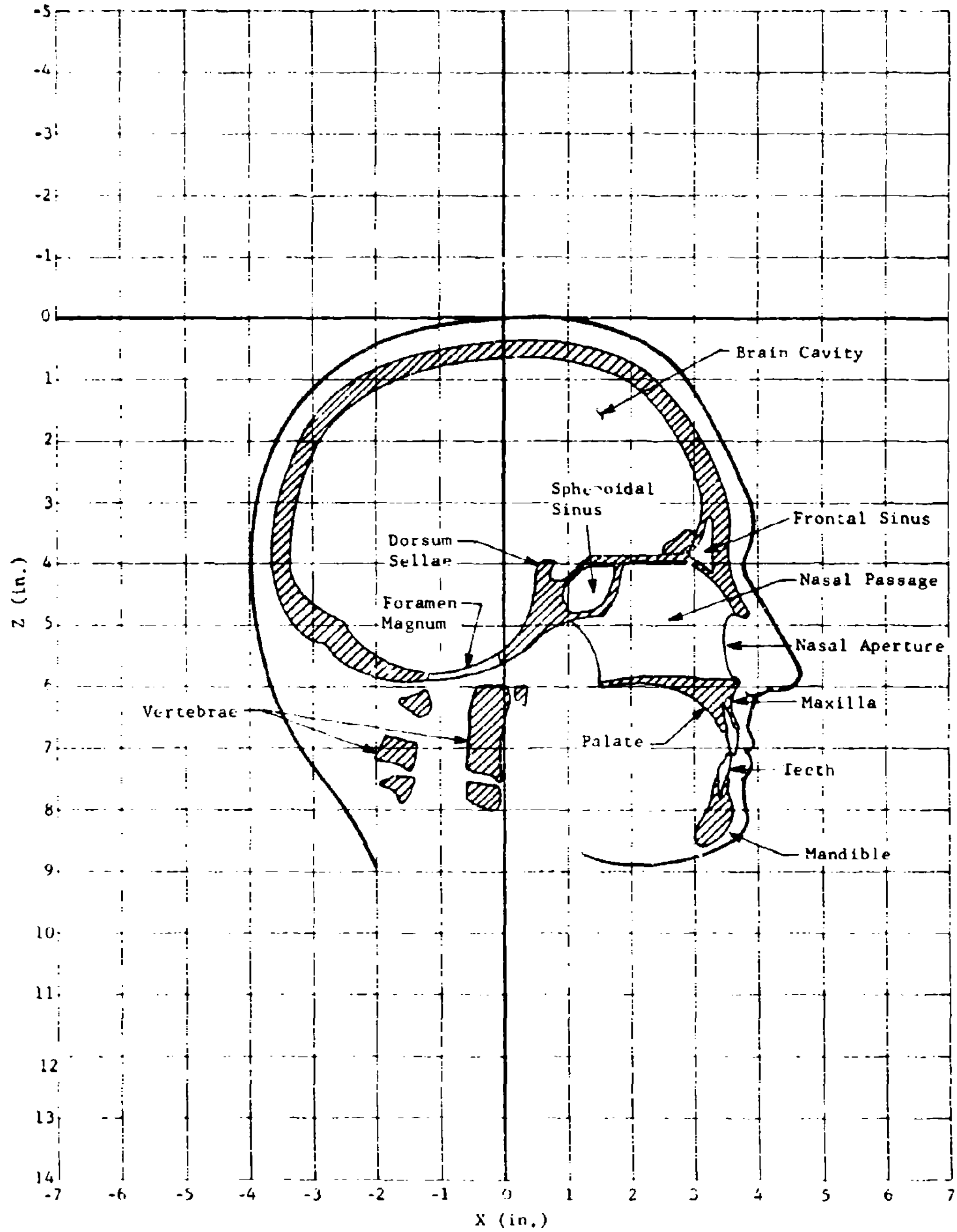


Figure 28 (C) Vertical Section of Head, Normal to Y-Axis at Center

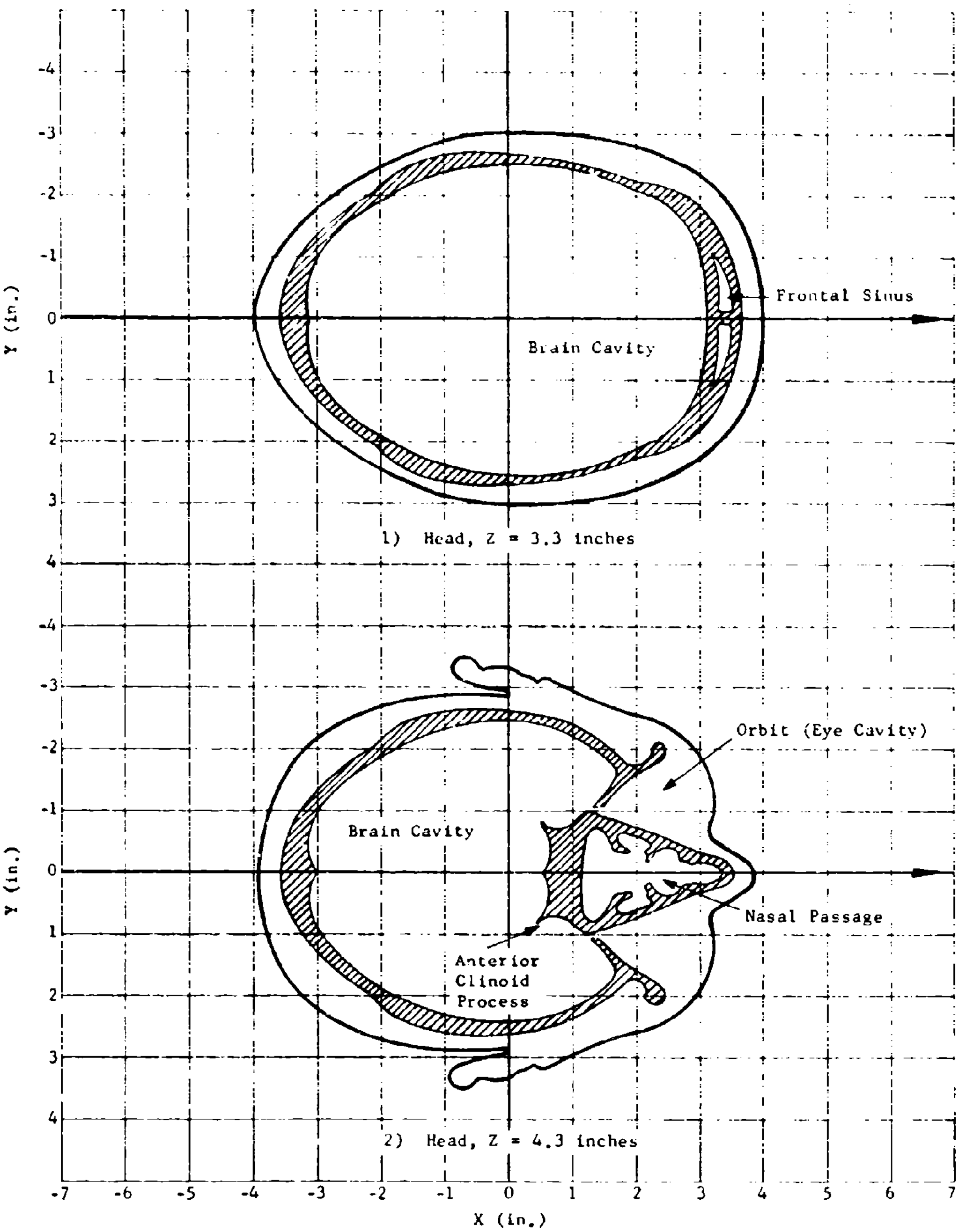
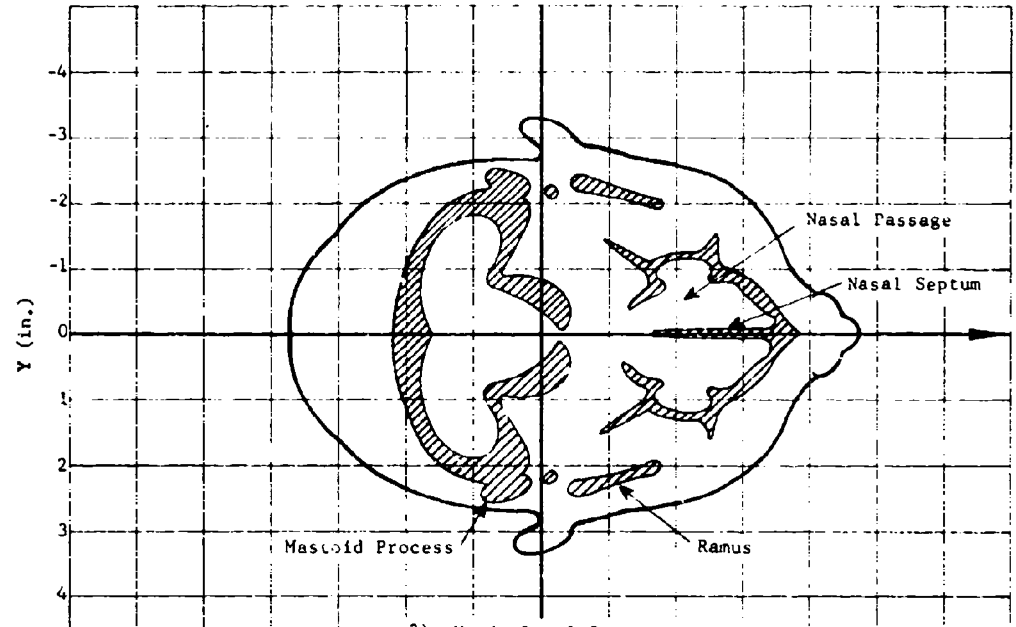
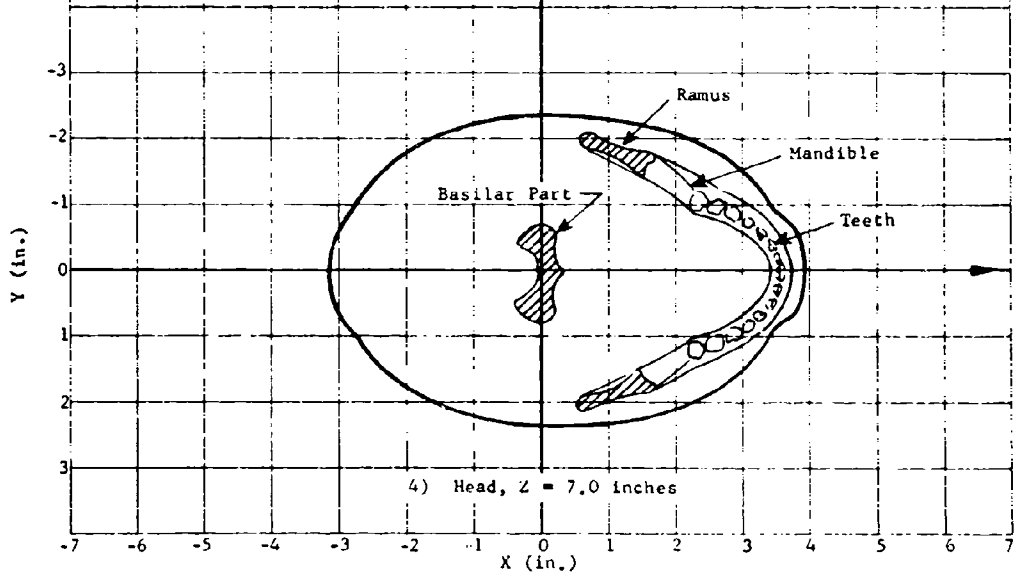


Figure 29 Horizontal Sections of Head, Torso, Leg and Foot



3) Head, Z = 5.7 inches



4) Head, Z = 7.0 inches

Figure 29 (cont)

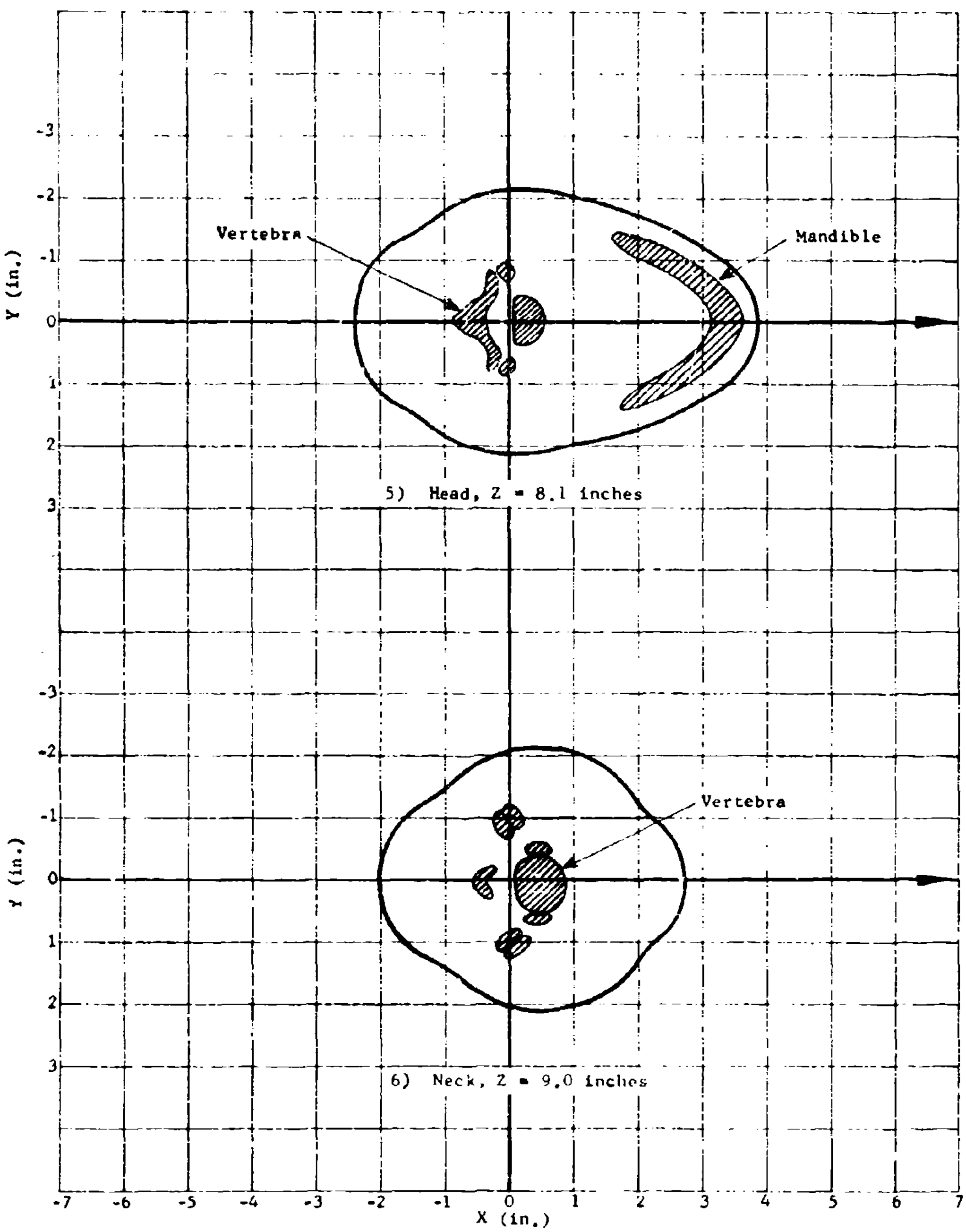
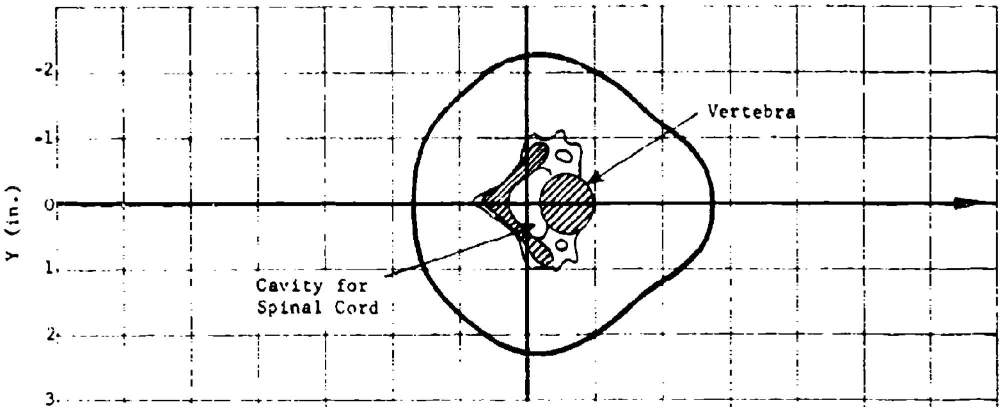
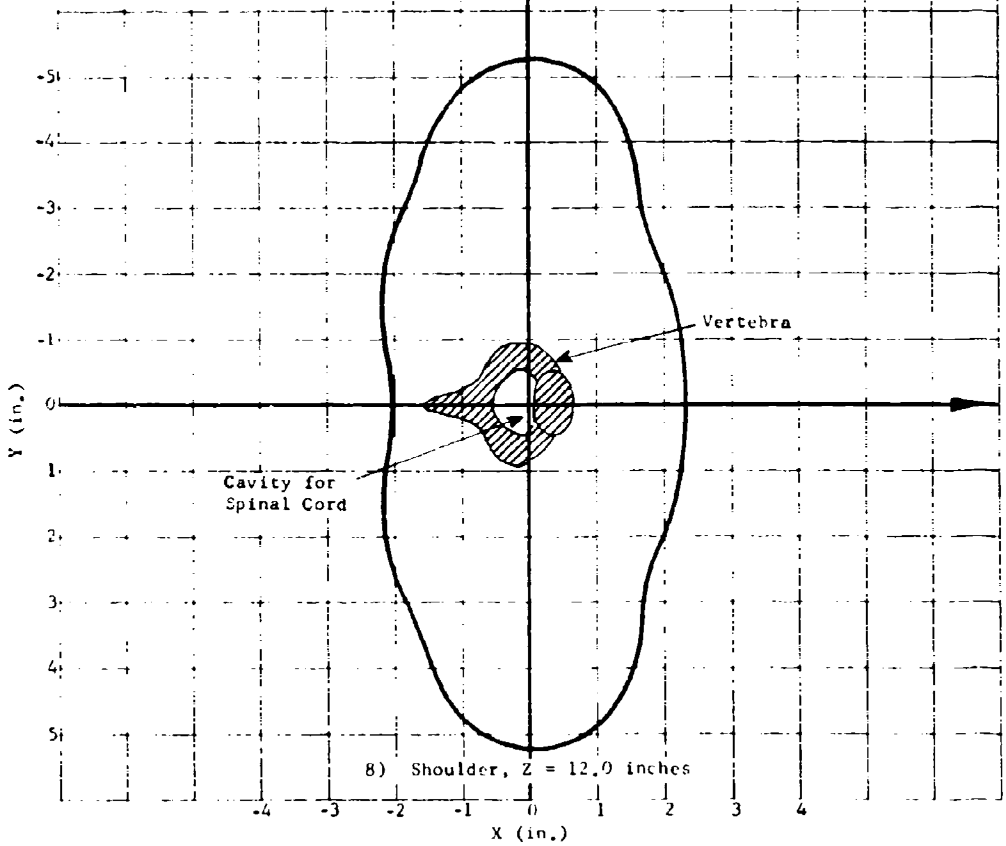


Figure 29 (cont)



7) Neck, Z = 10.4 inches



8) Shoulder, Z = 12.0 inches

Figure 29 (cont)

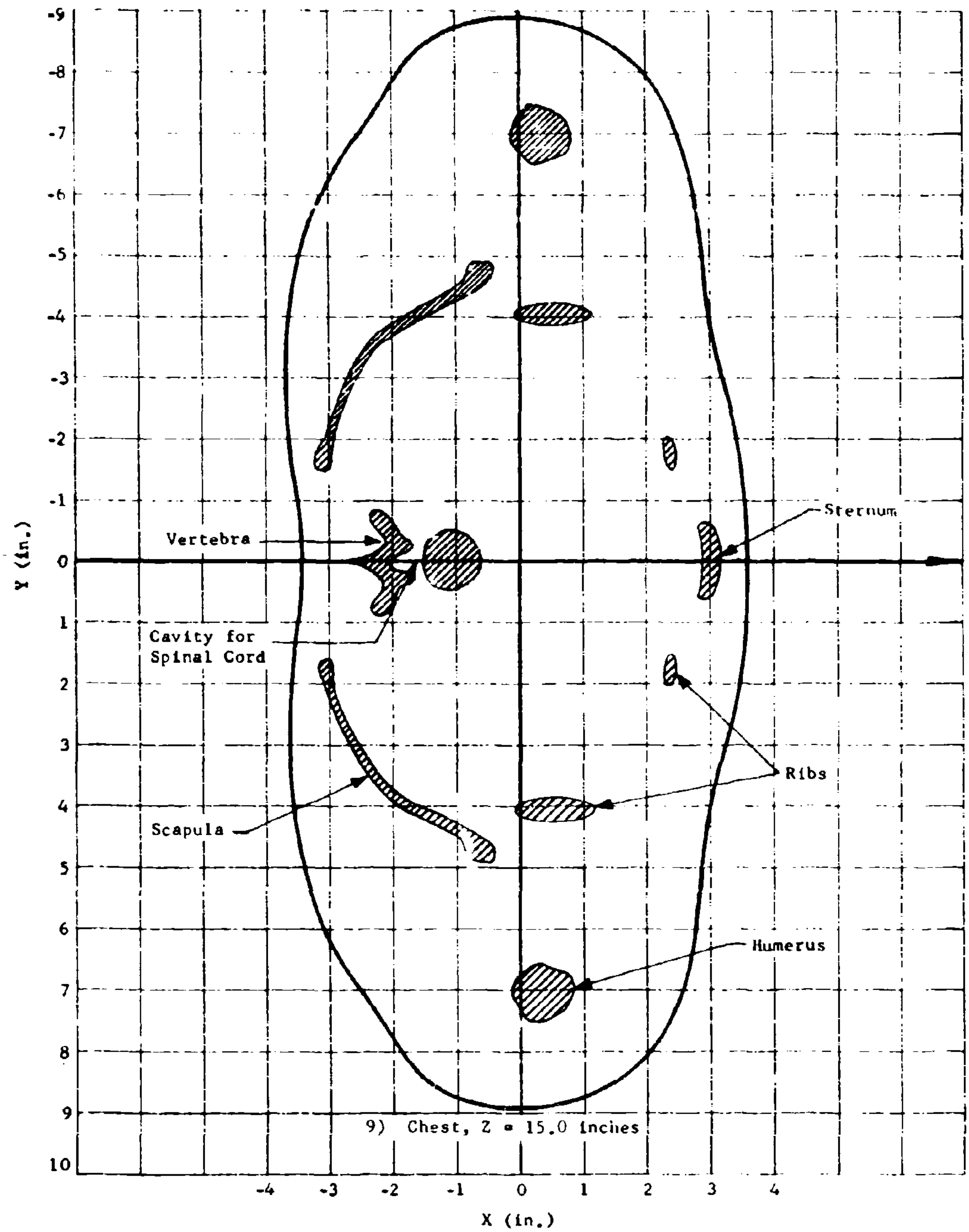


Figure 29 (cont)

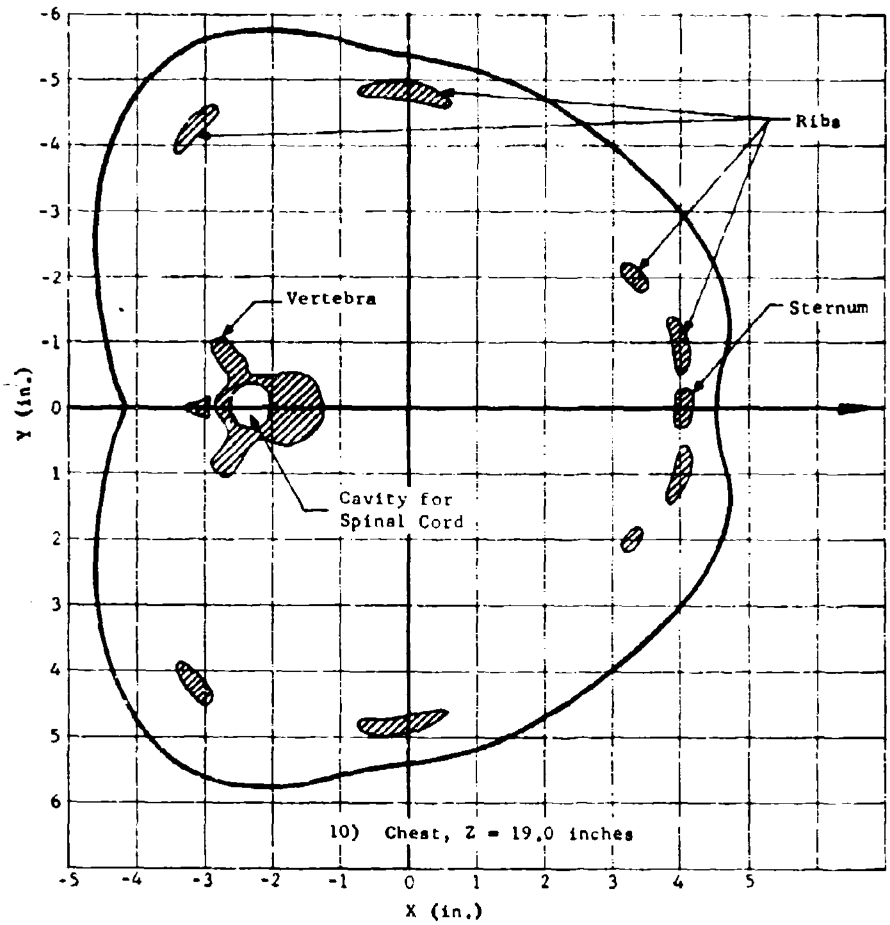


Figure 29 (cont)

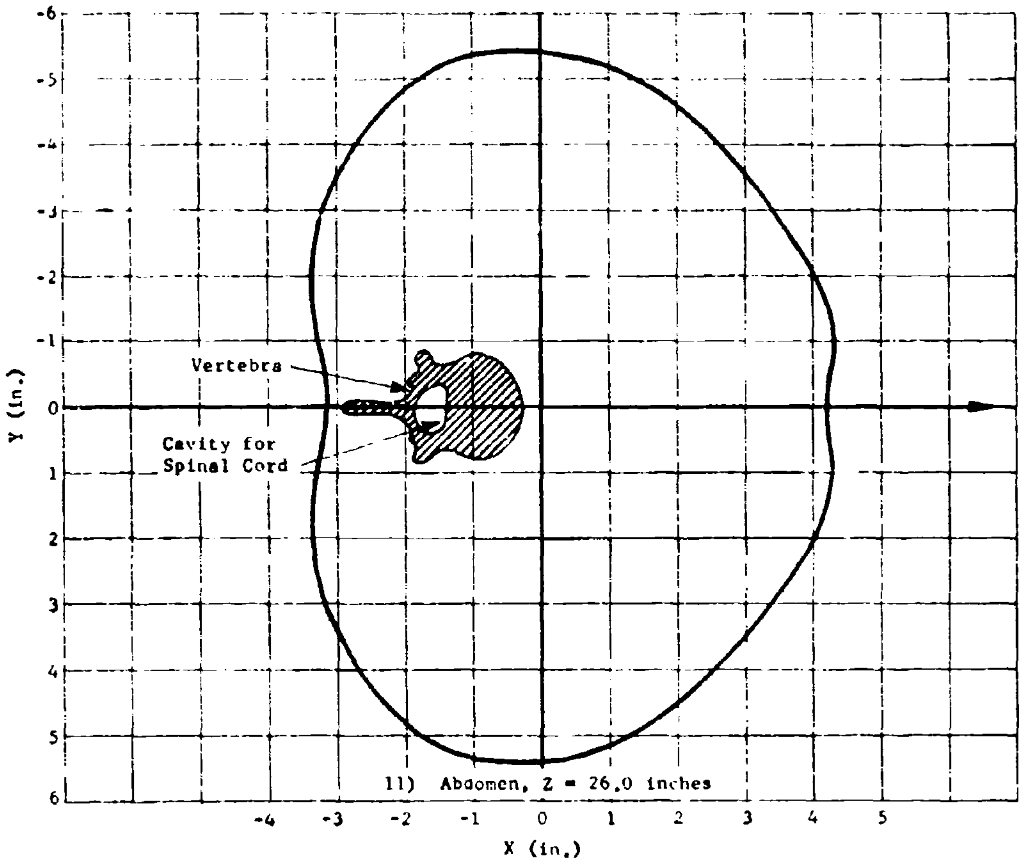


Figure 29 (cont)

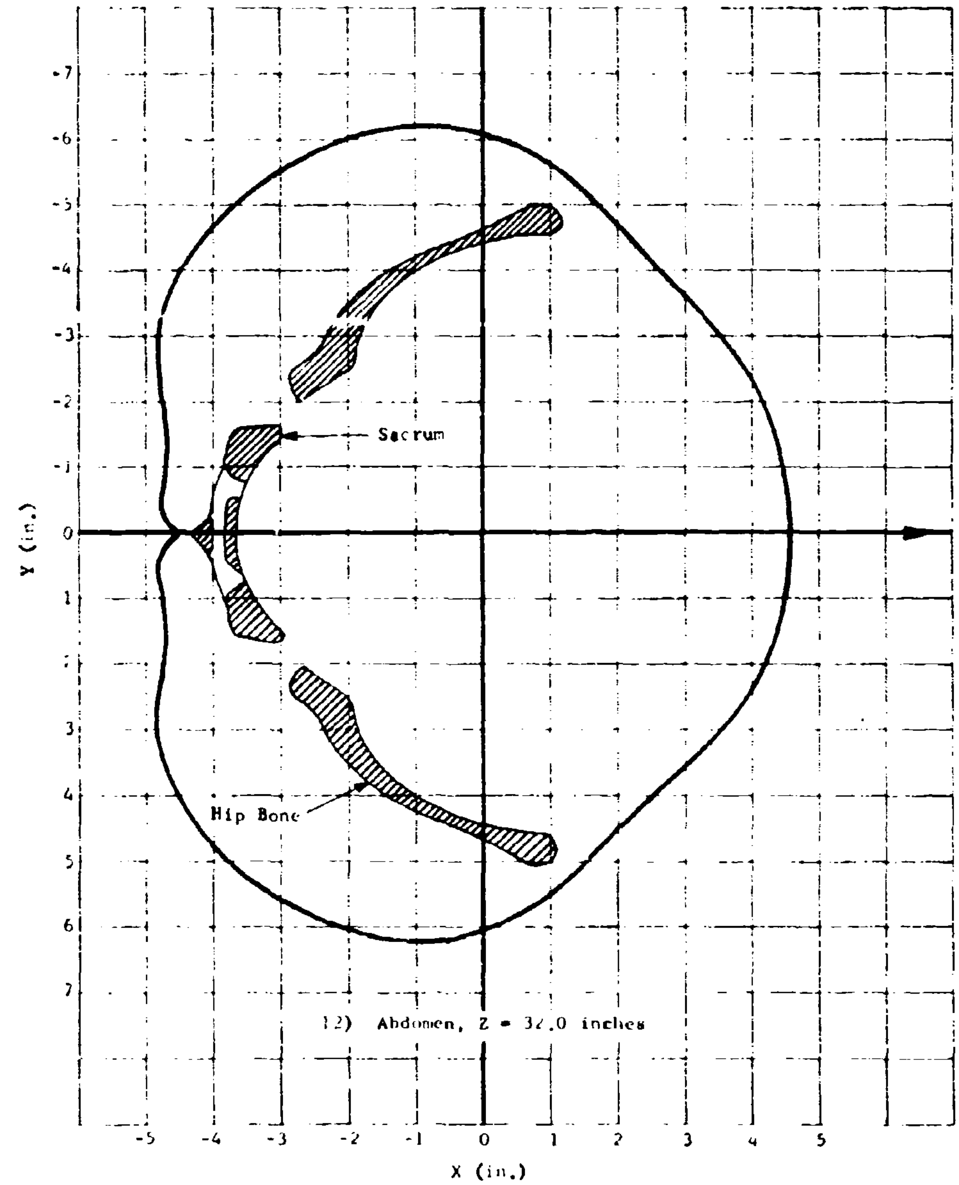


Figure 29 (cont)

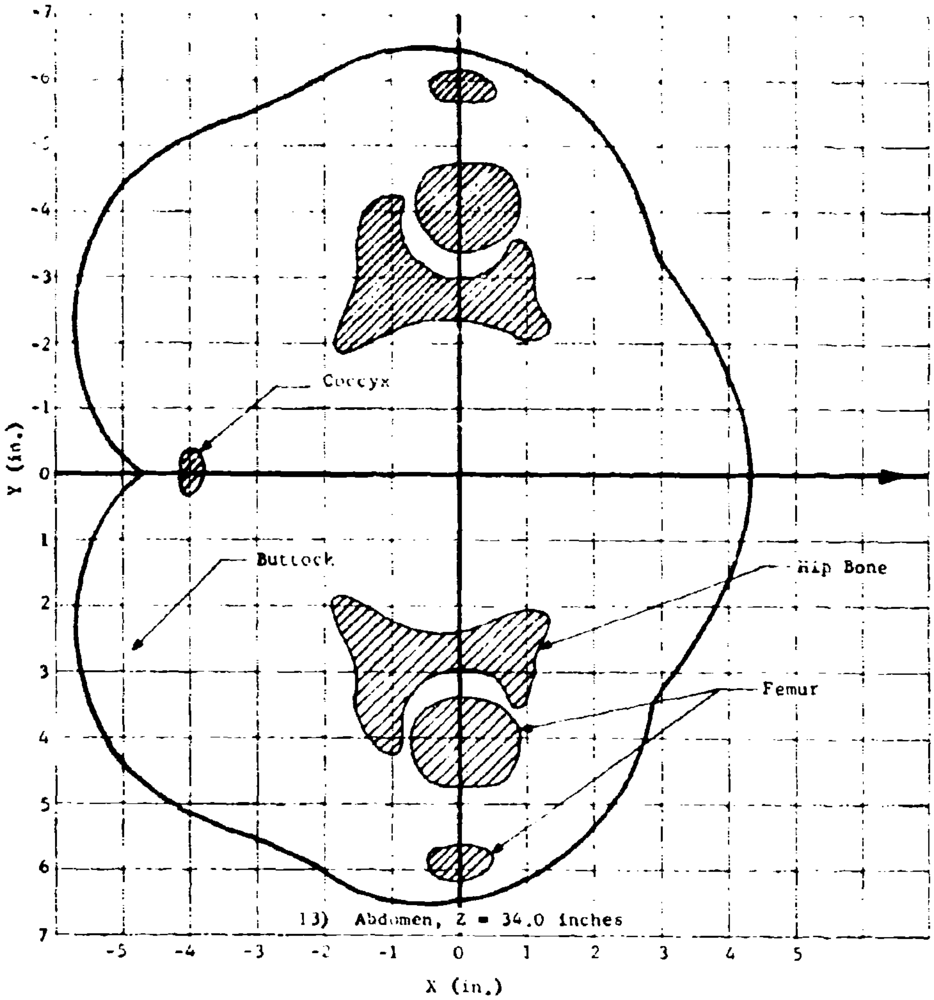


Figure 19 (cont)

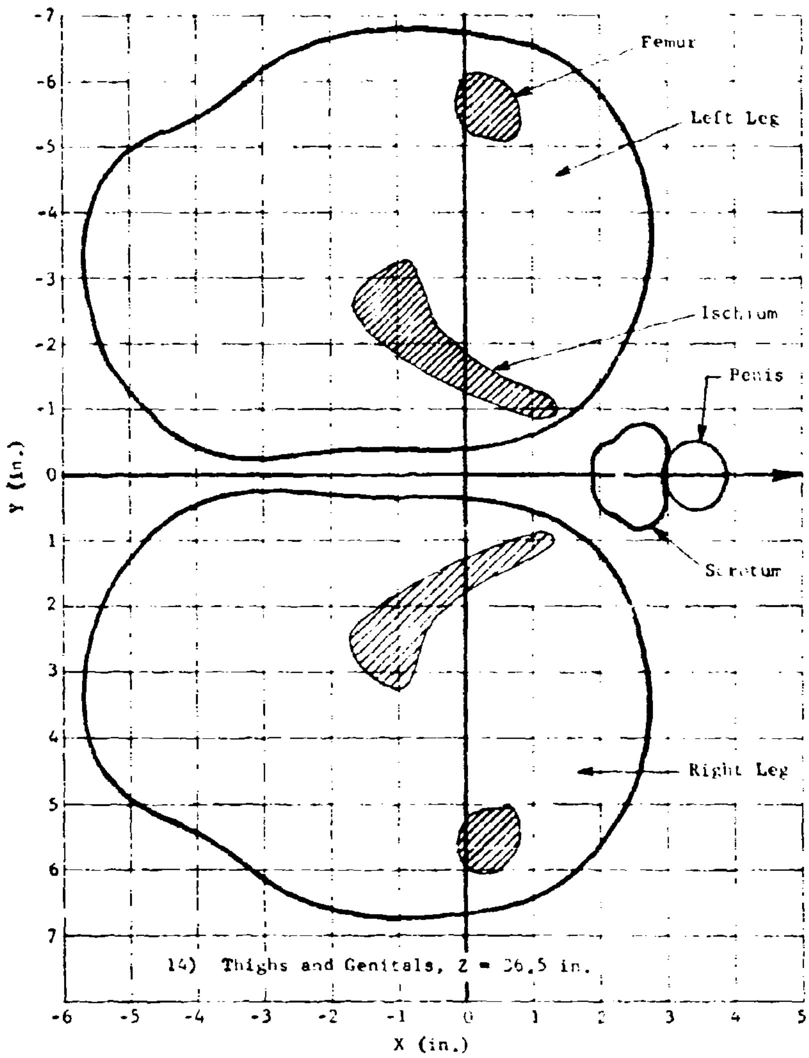


Figure 25 (cont)

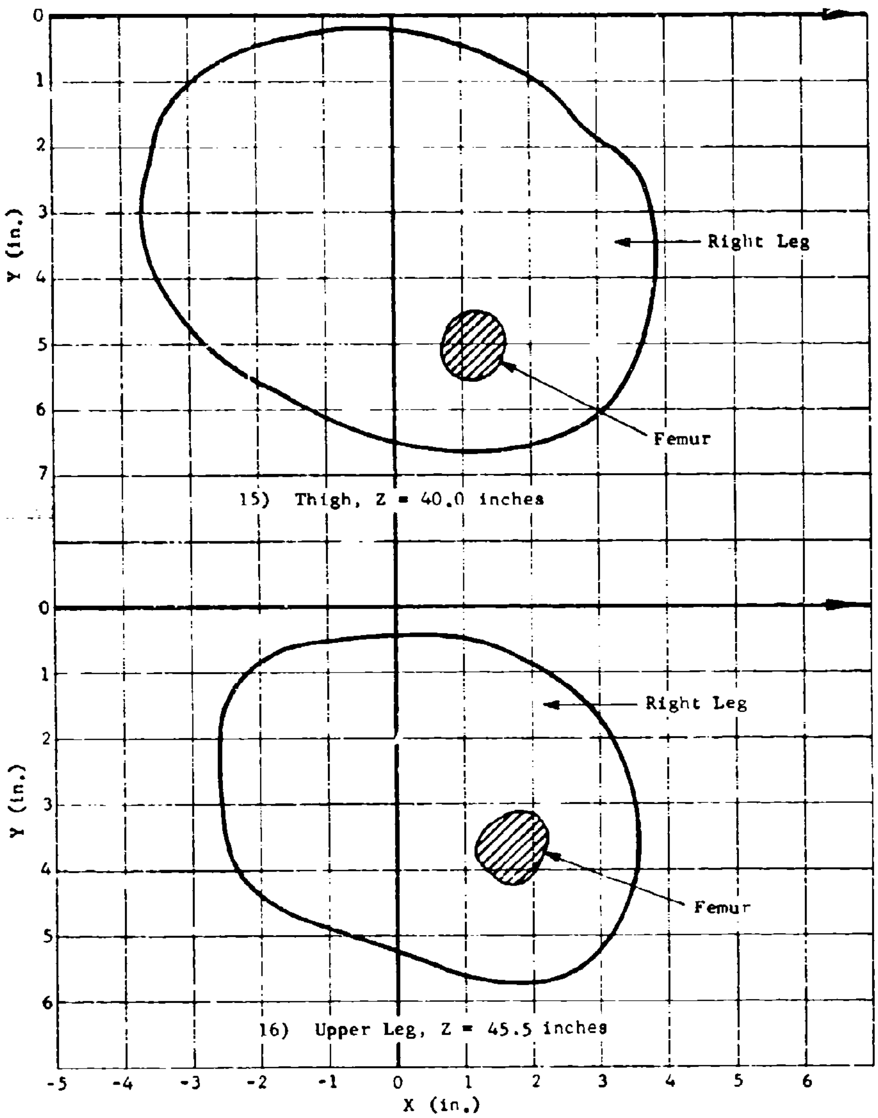


Figure 29 (cont)

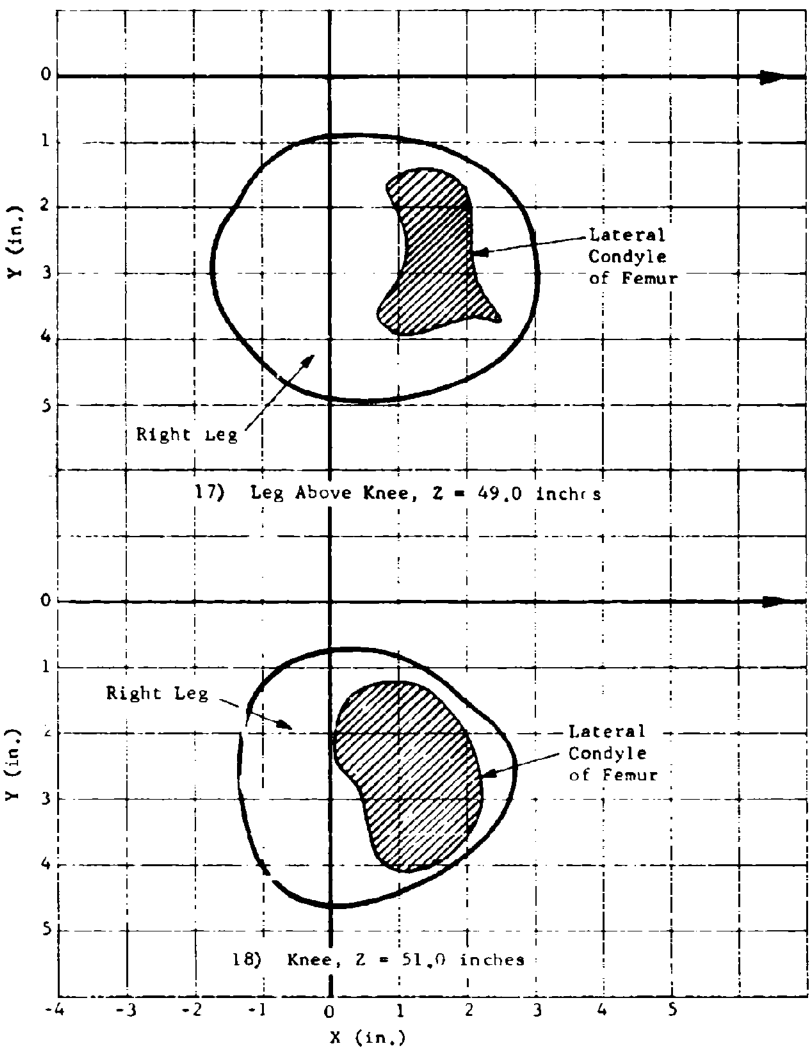


Figure 29 (cont)

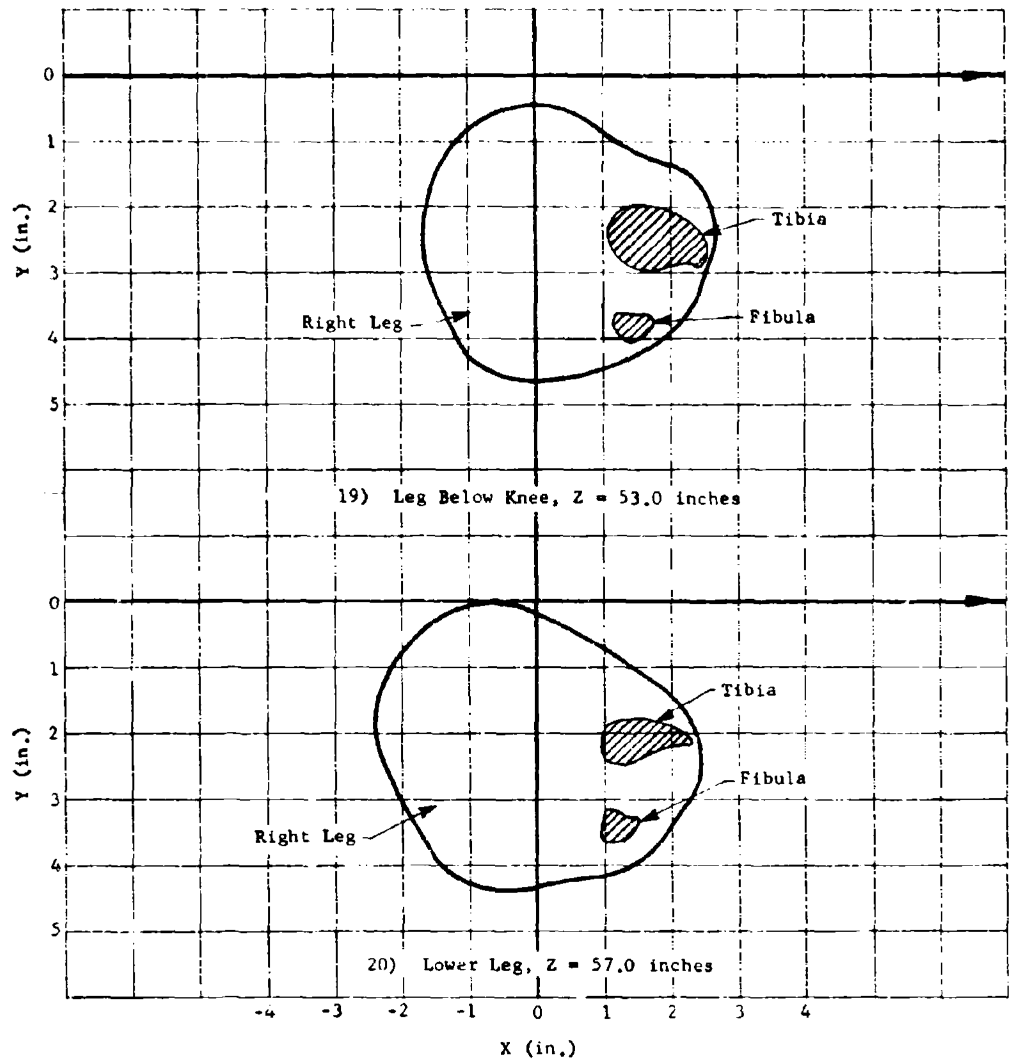


Figure 29 (cont)

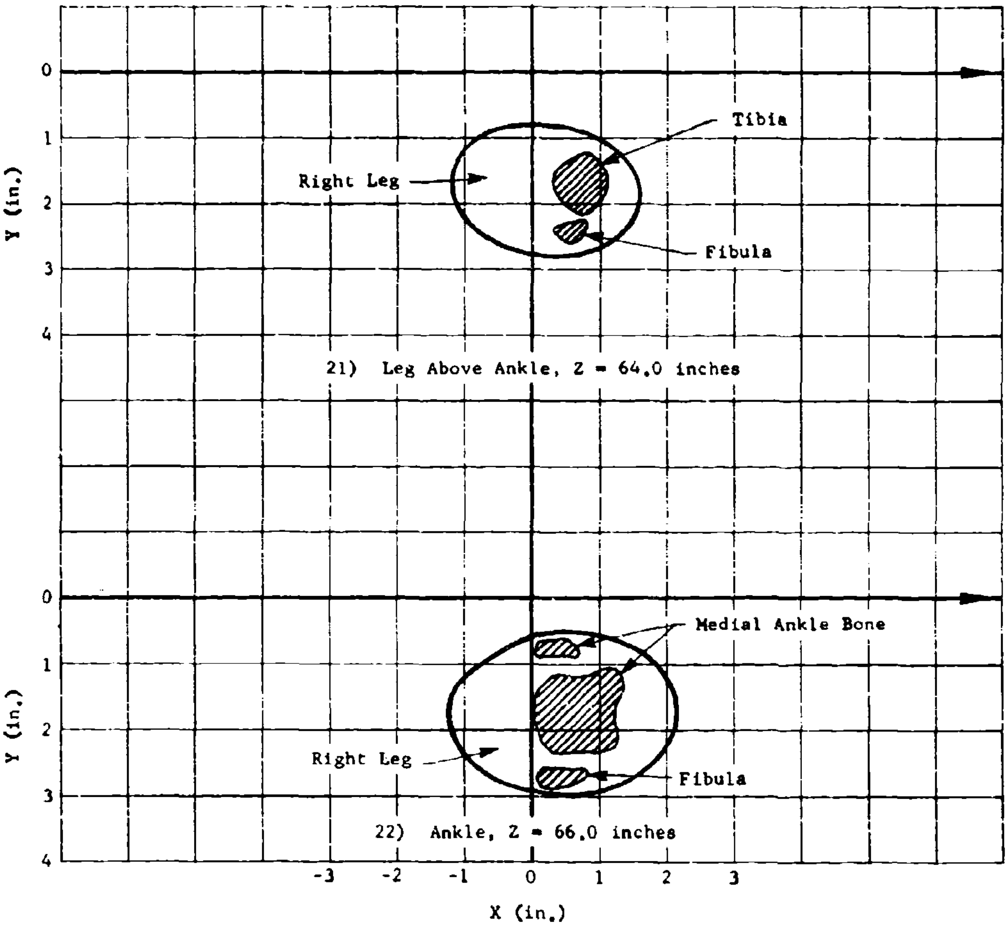
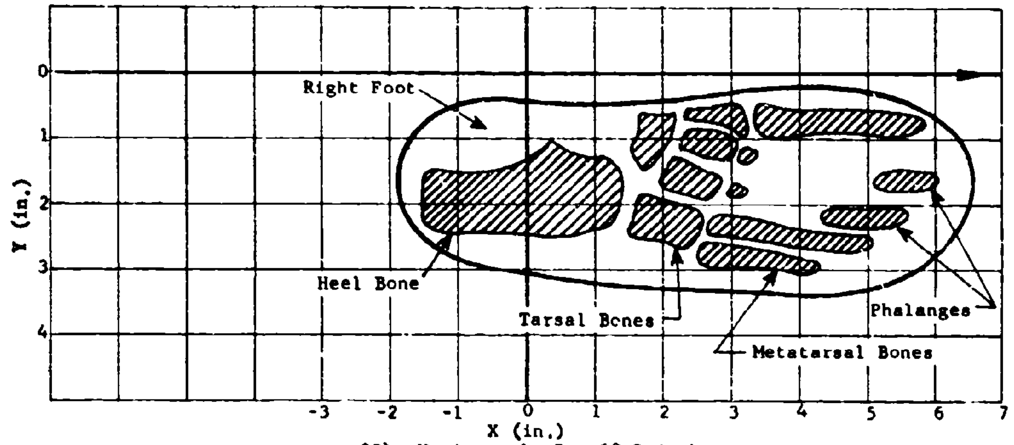
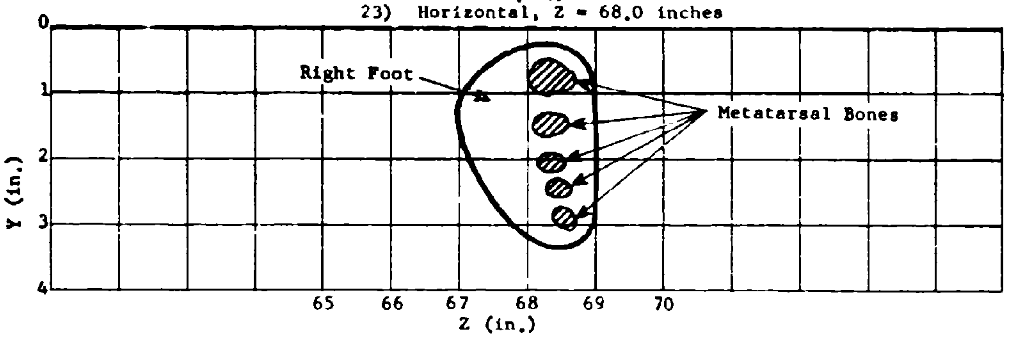


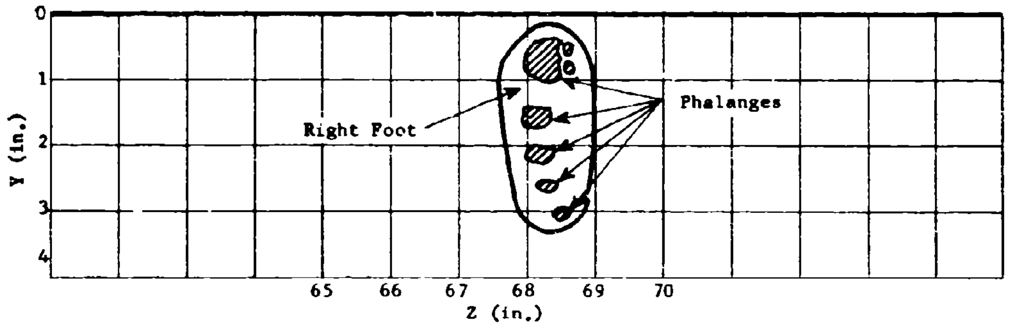
Figure 29 (concl)



23) Horizontal, Z = 68.0 inches



24) Vertical, X = 40 inches



25) Vertical, X = 6.0 inches

Figure 30 Sections of Foot

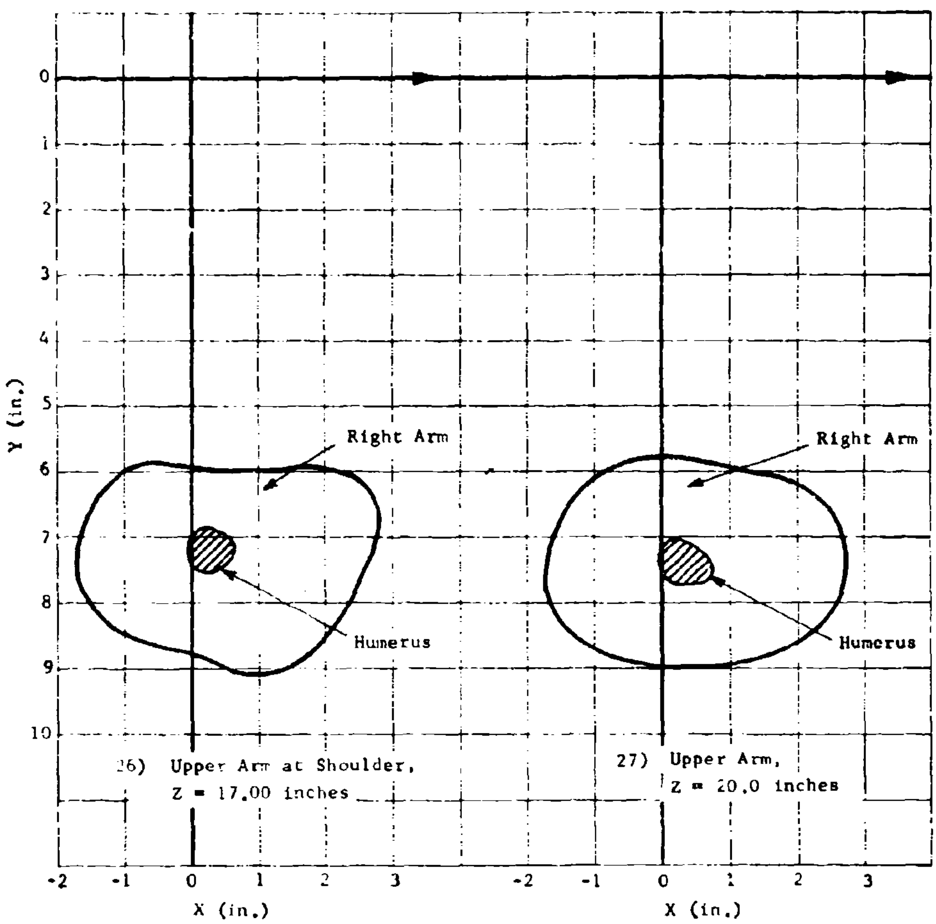


Figure 31 Horizontal Sections of Arm and Genitals

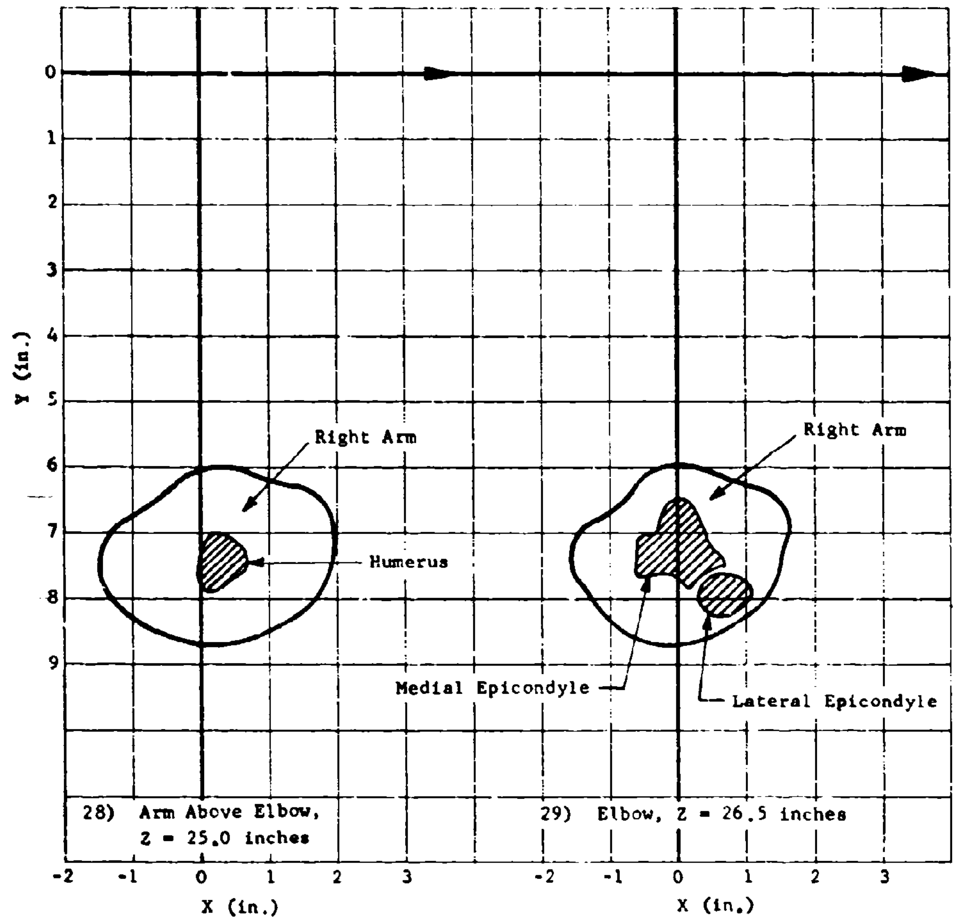


Figure 31 (cont)

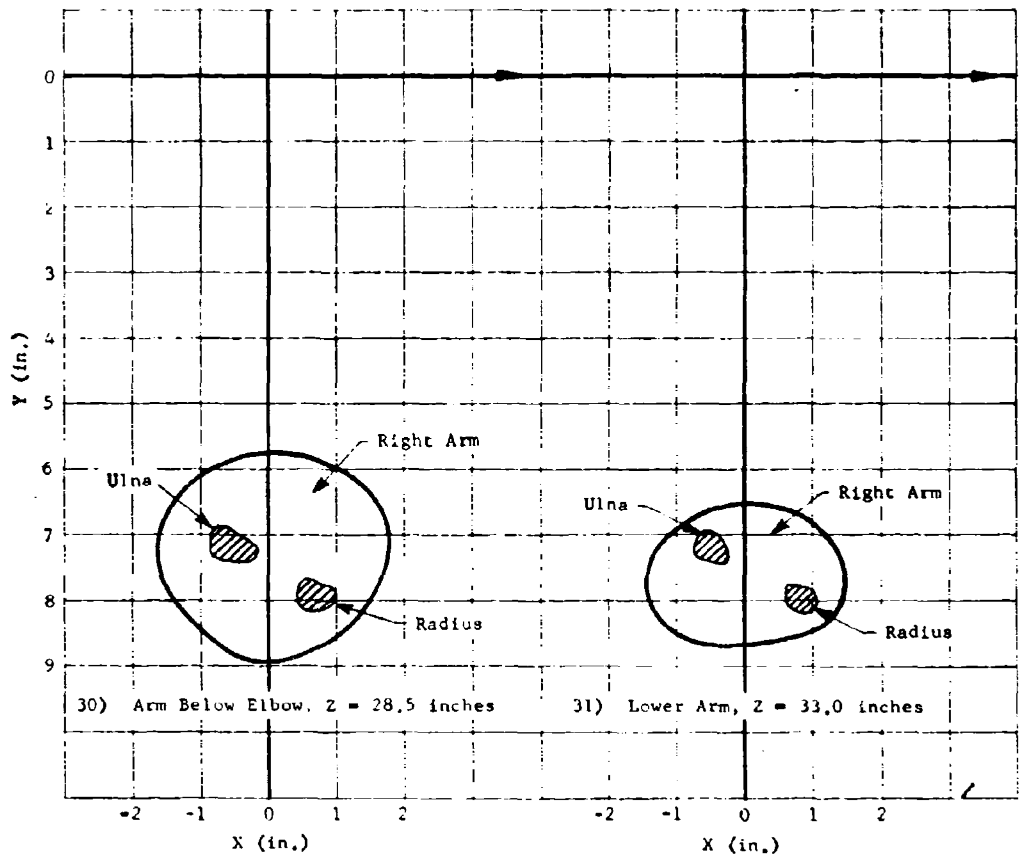


Figure 31 (cont)

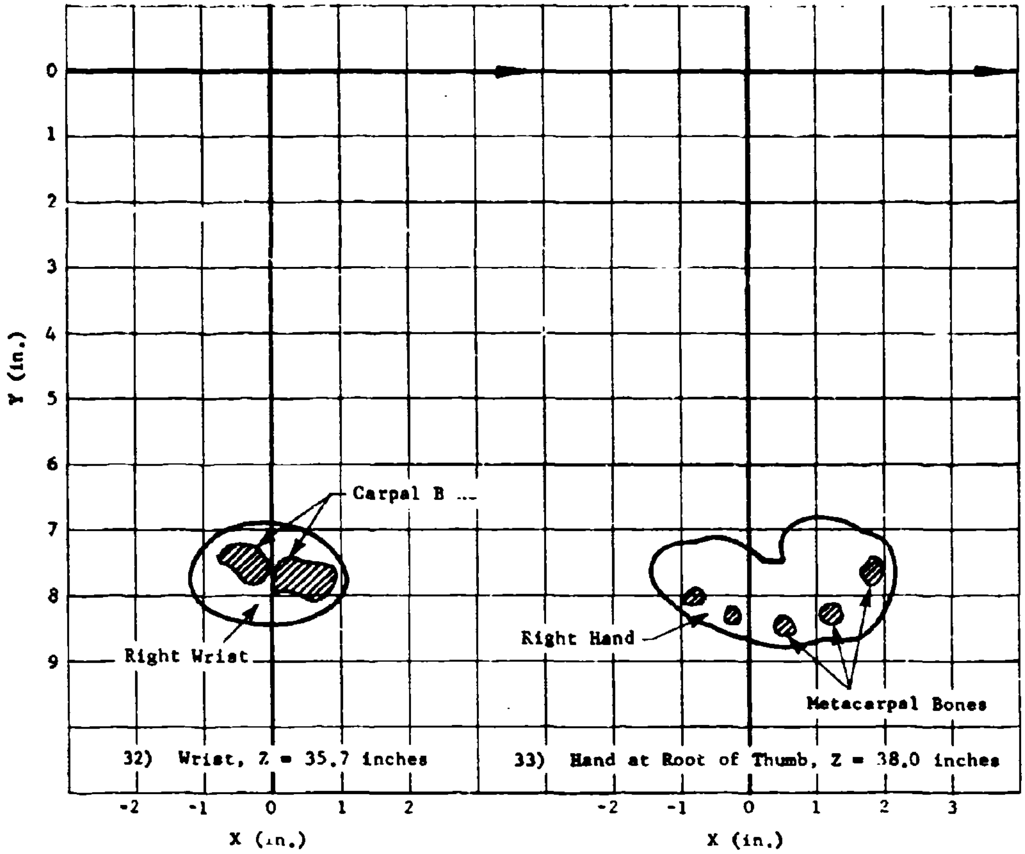
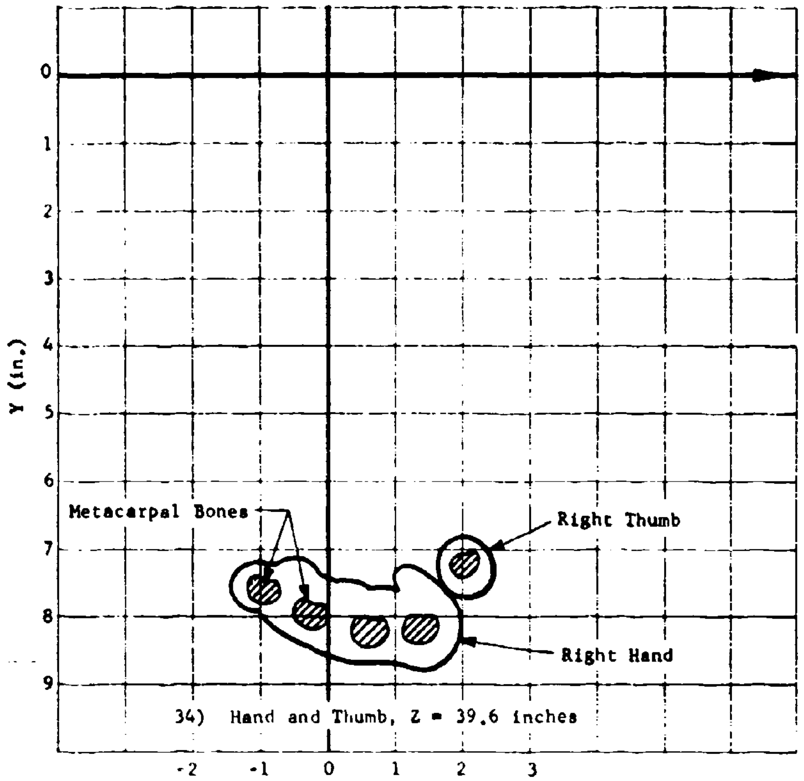


Figure 31 (cont)



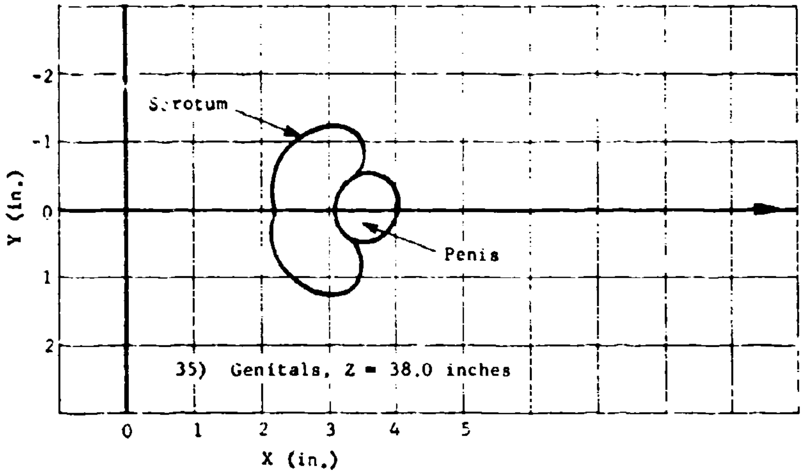


Figure 31 (cont)

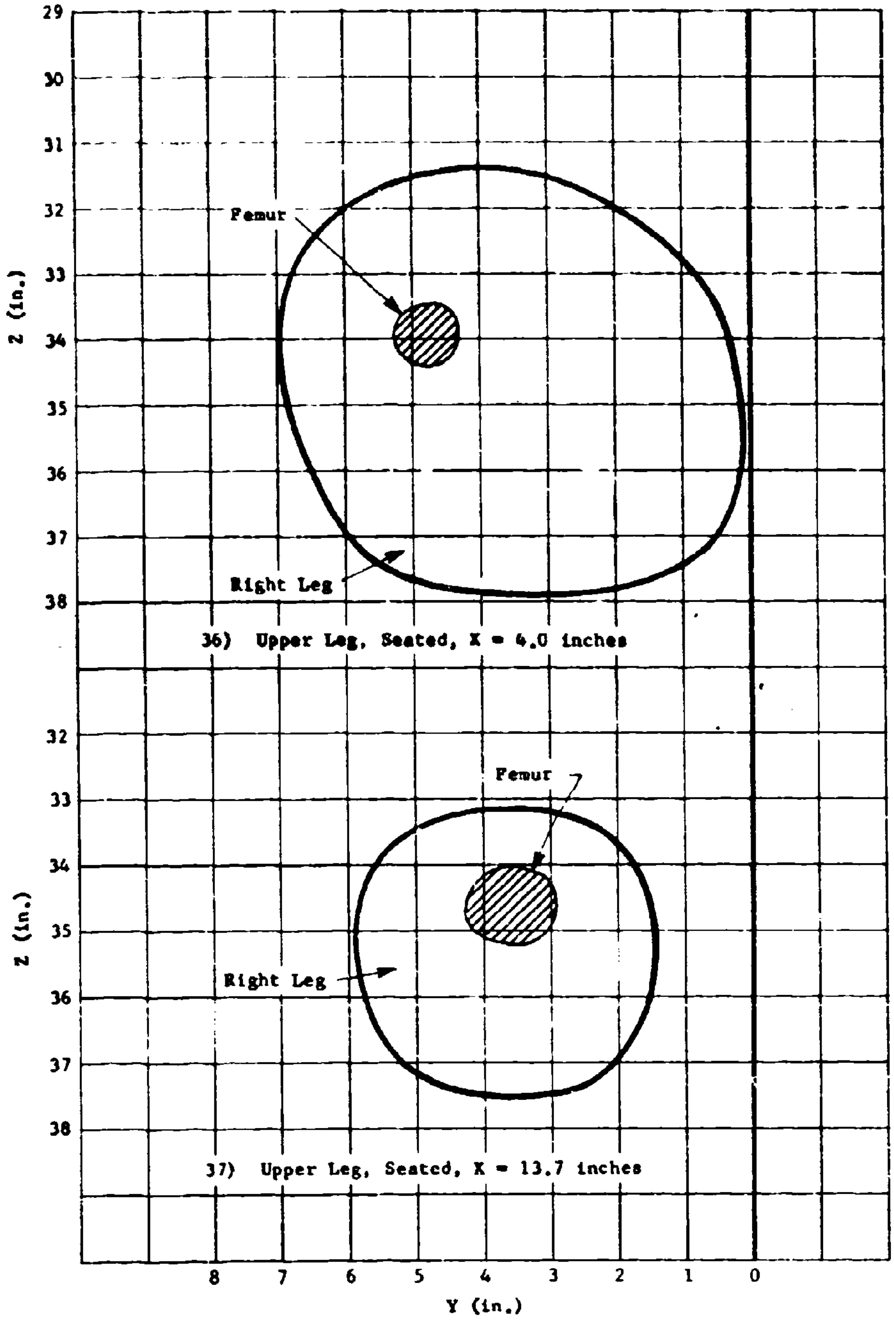


Figure 31 (concl)

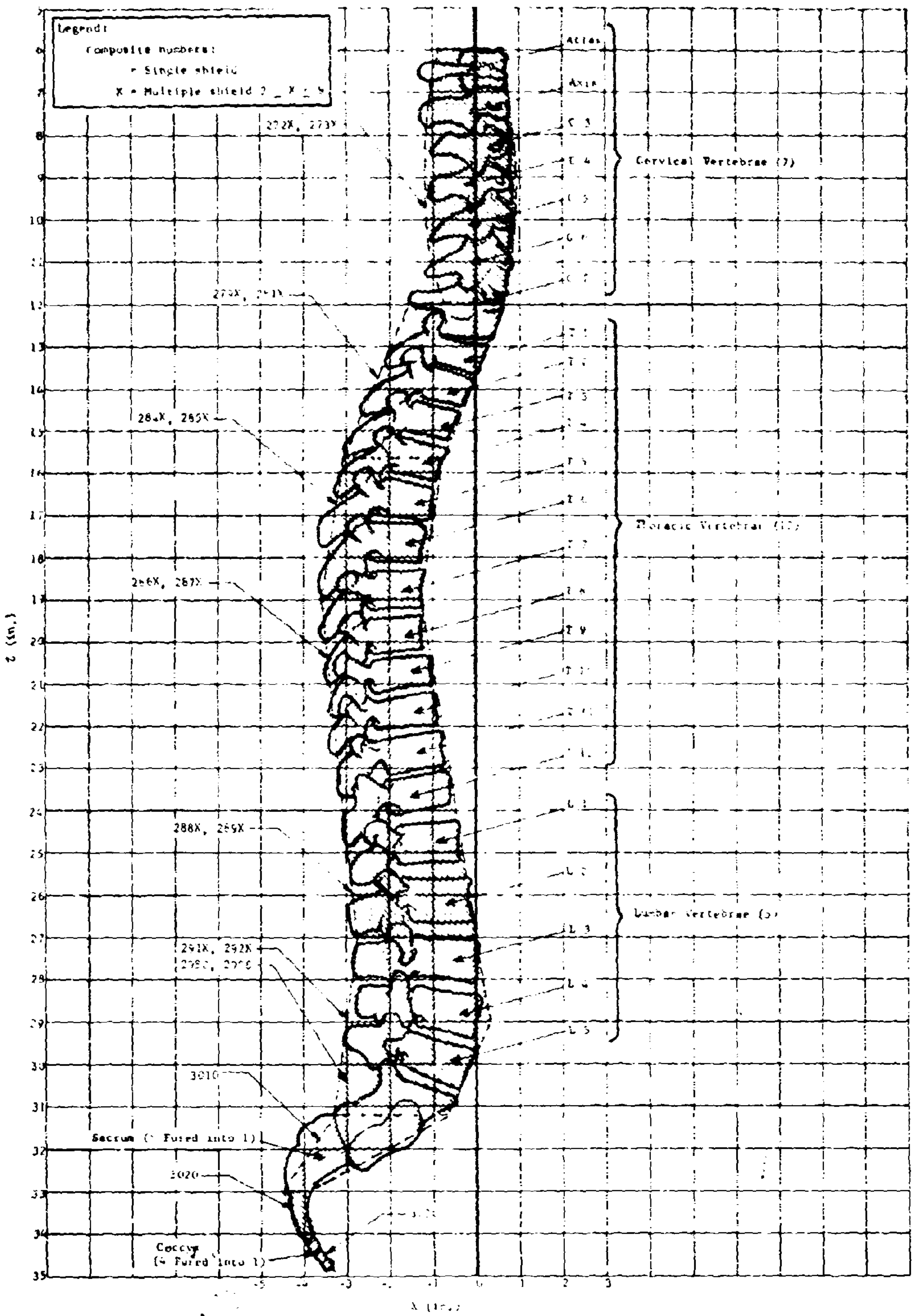


Figure 32 Spinal Column

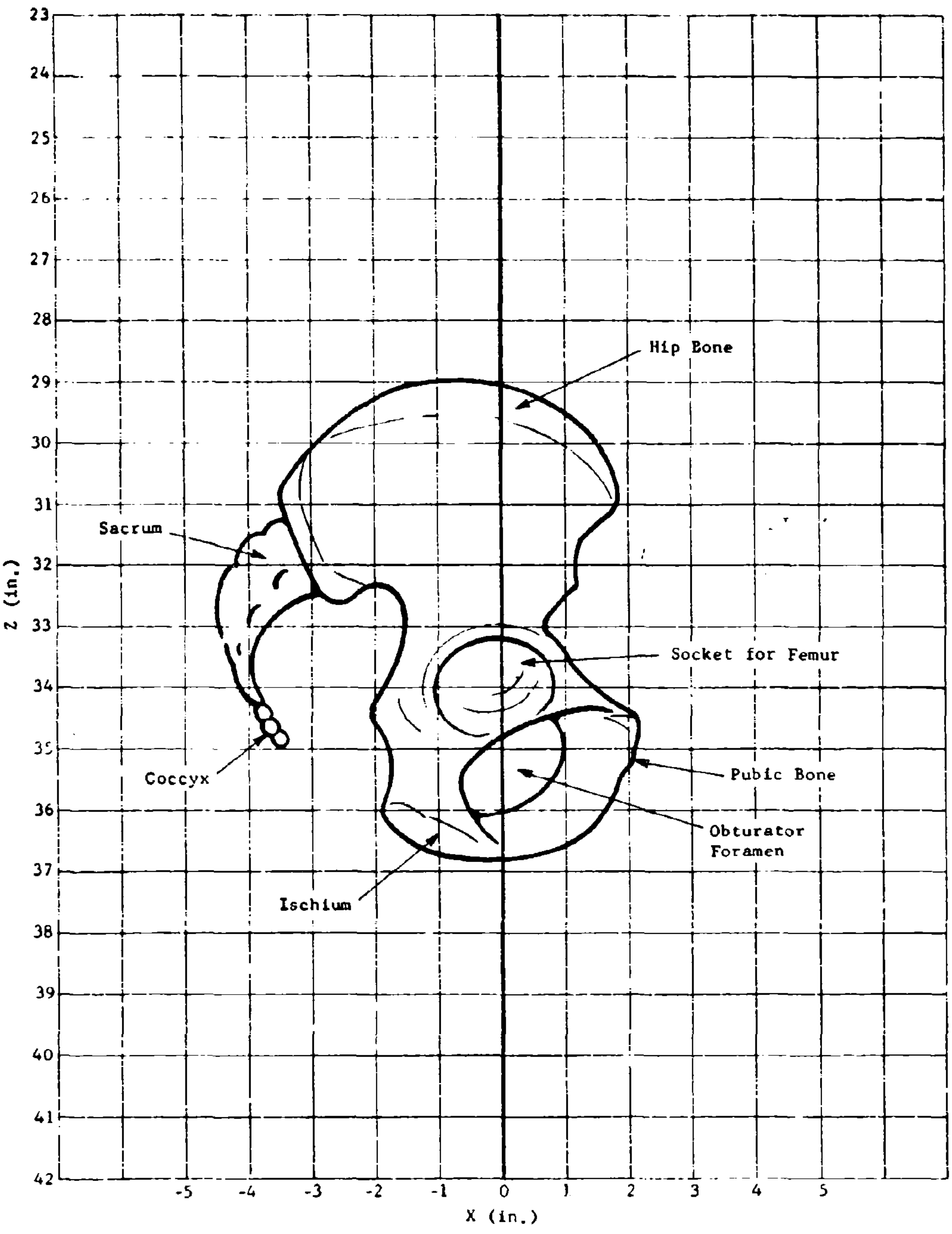


Figure 33 Pelvic Girdle

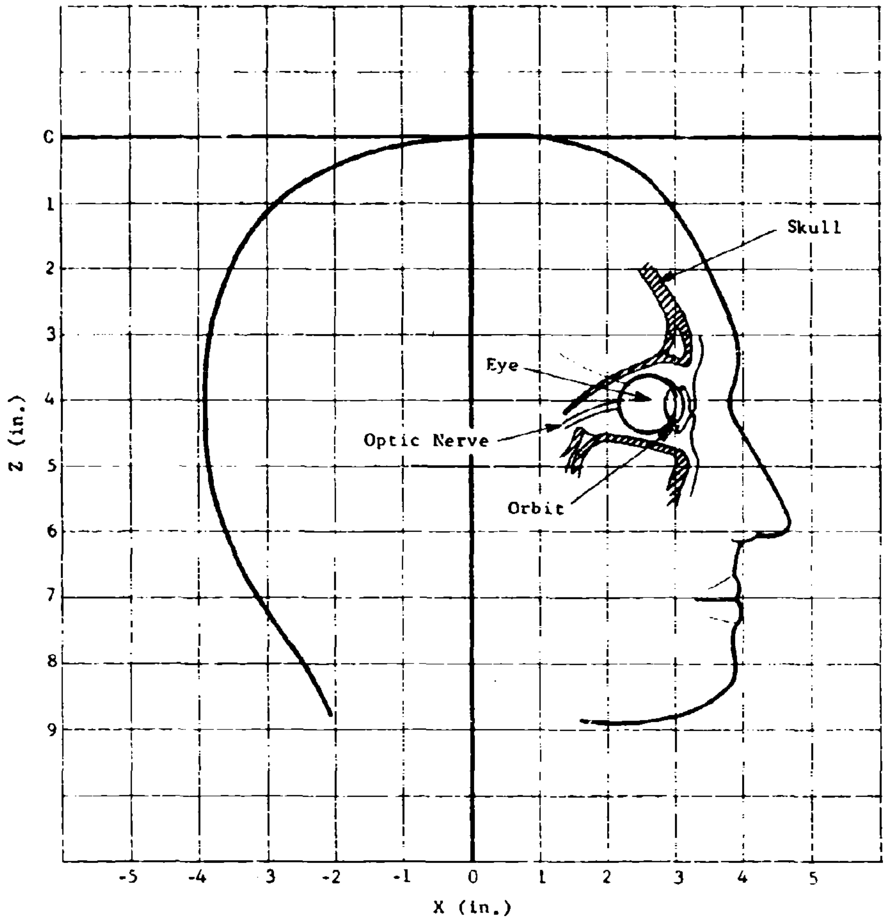
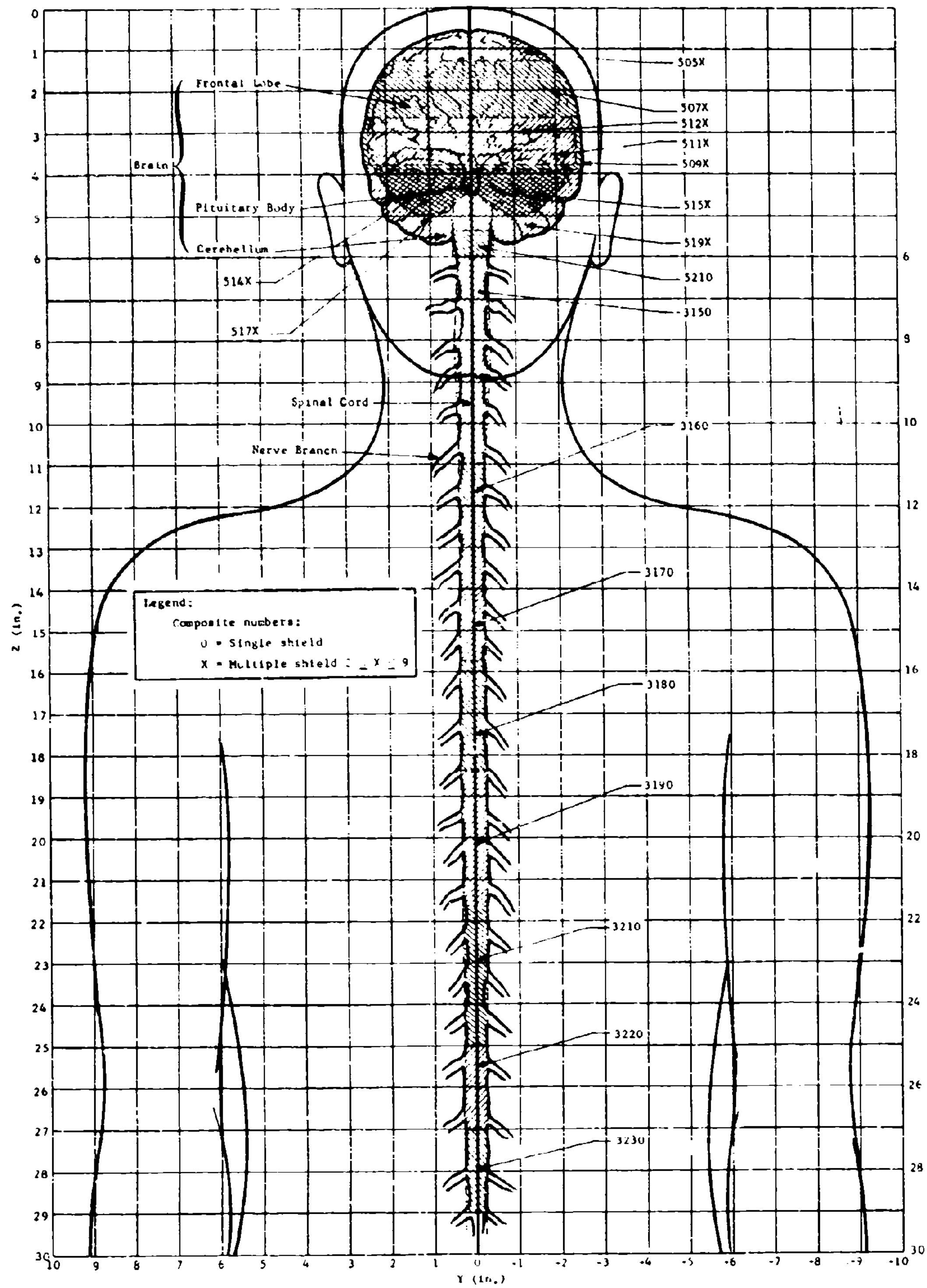
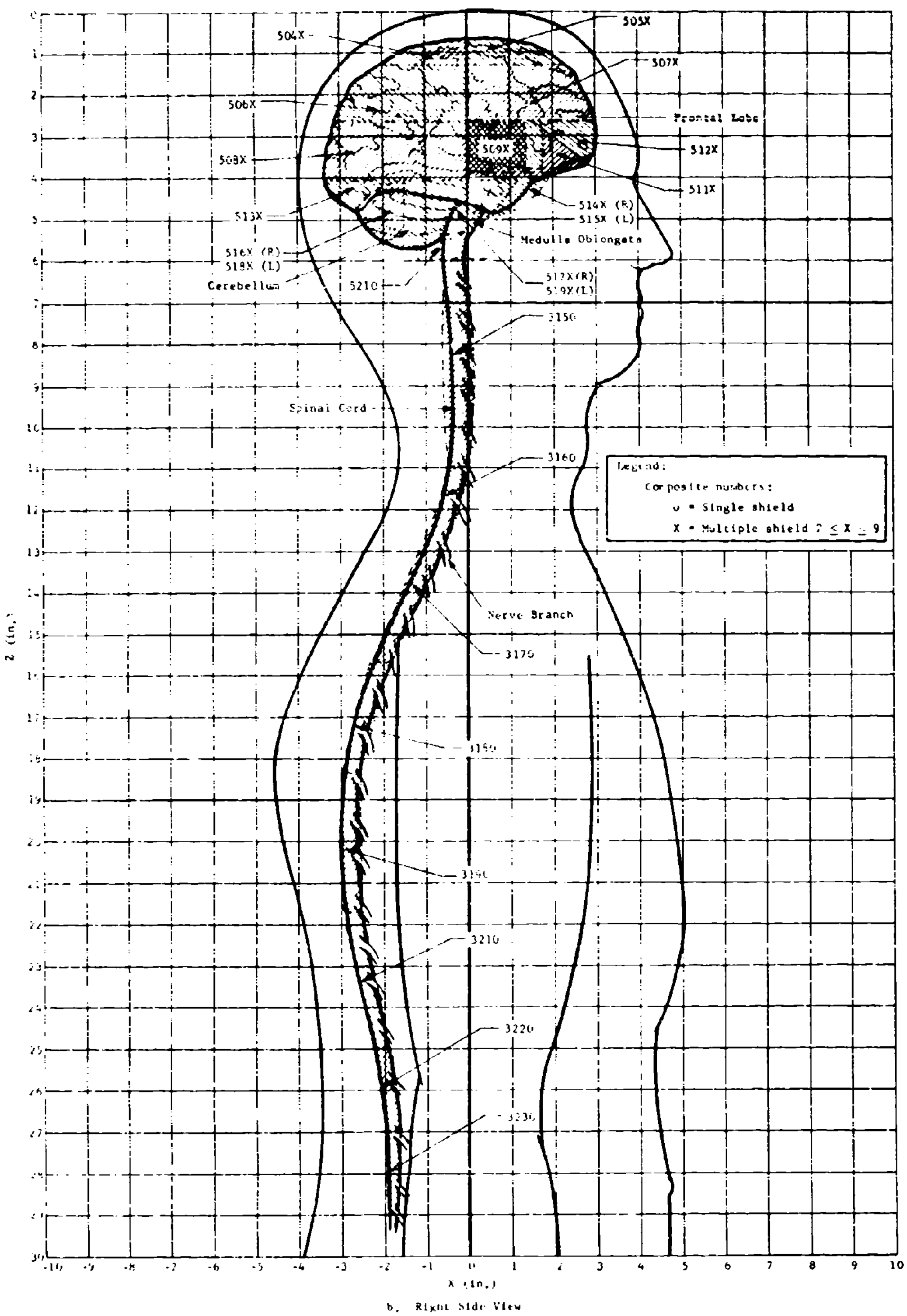


Figure 34 Eye Location



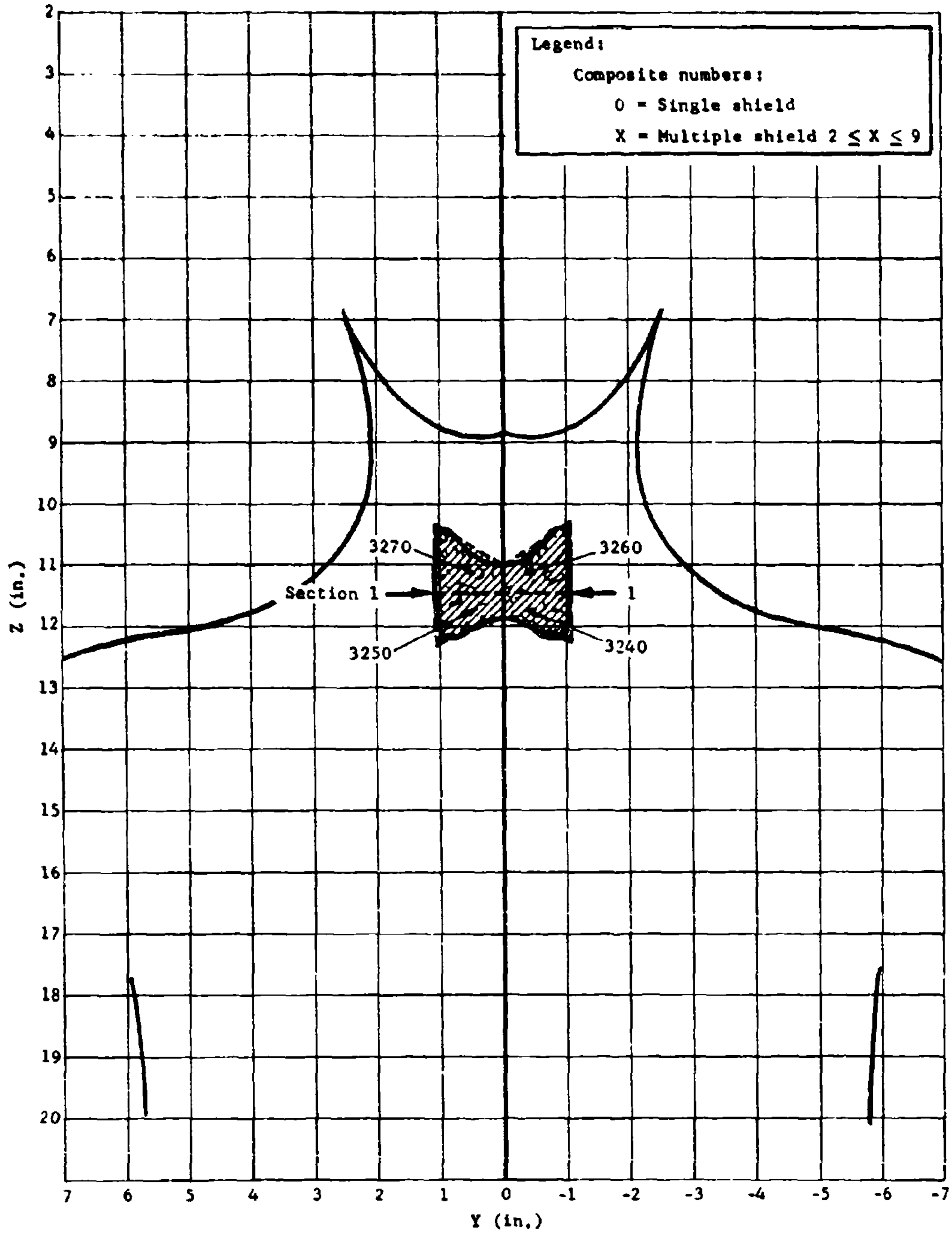
a. Front View

Figure 35 Central Nervous System, Brain and Spinal Cord



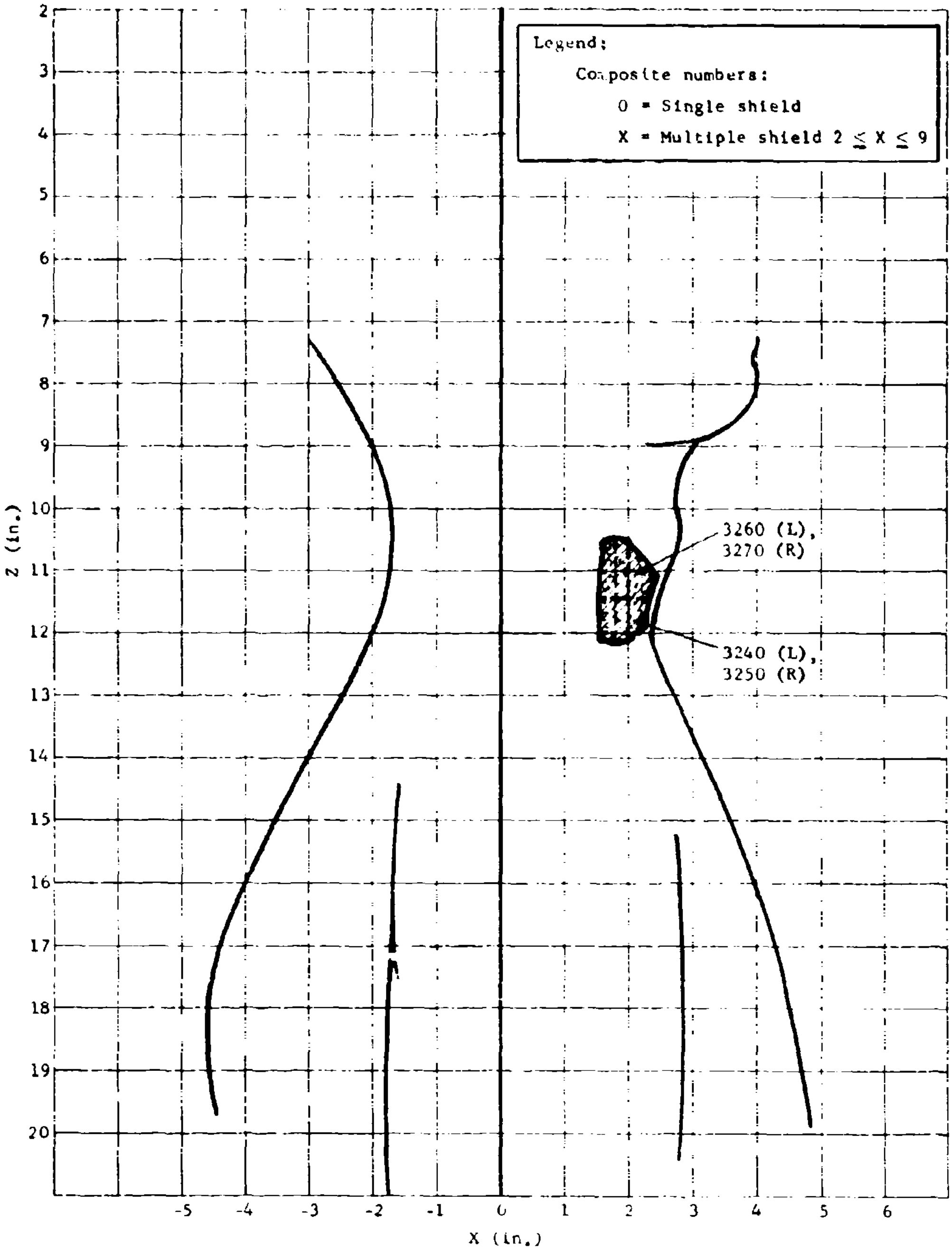
b. Right Side View

Figure 35 (concl)



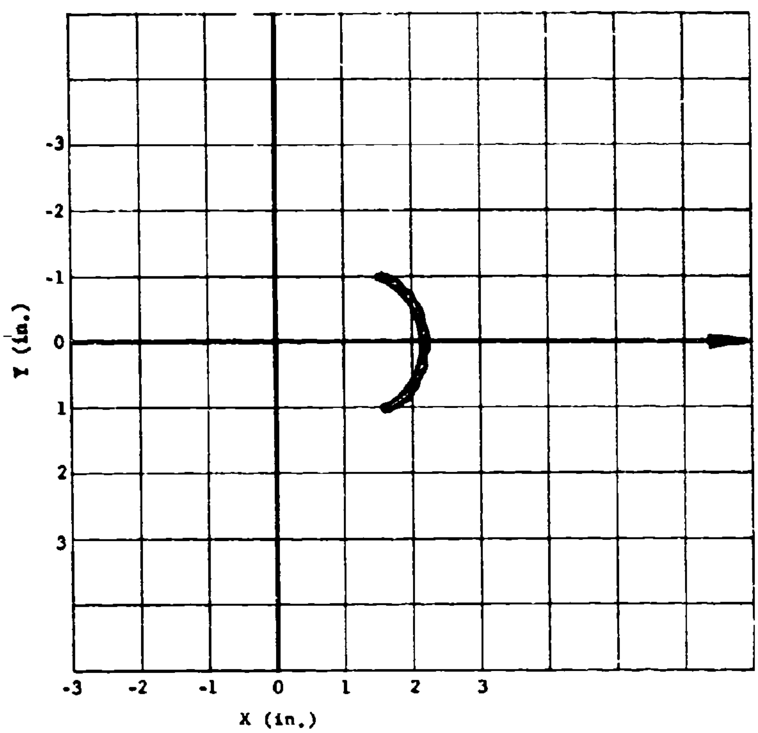
a. Front View

Figure 36 Thyroid



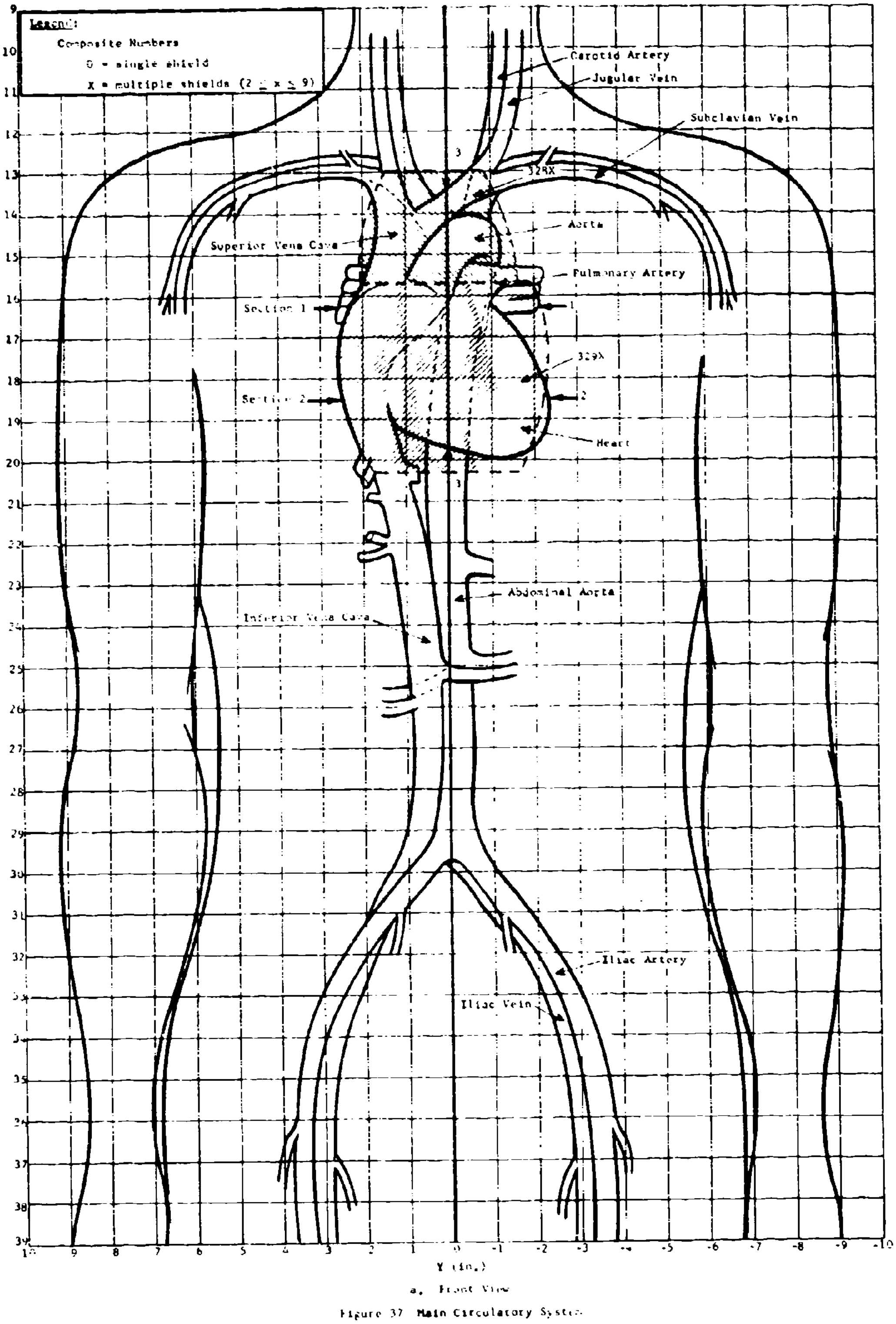
b. Right Side View

Figure 36 (cont)



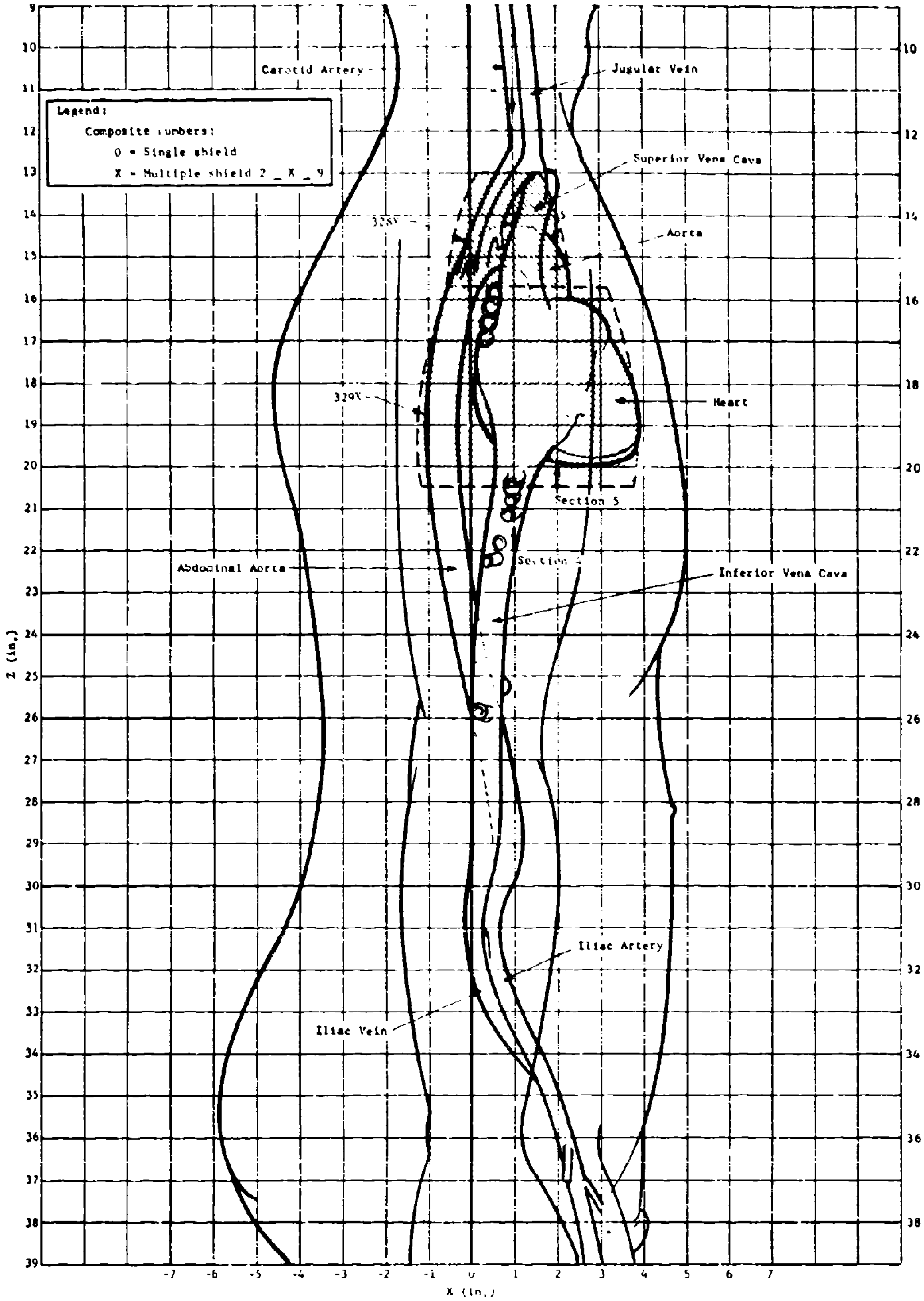
1) Horizontal Section, Z = 11.5 inches

Figure 36 (concl)



a. Front View

Figure 37 Main Circulatory System



b. Right Side View

Figure 37 (cont)

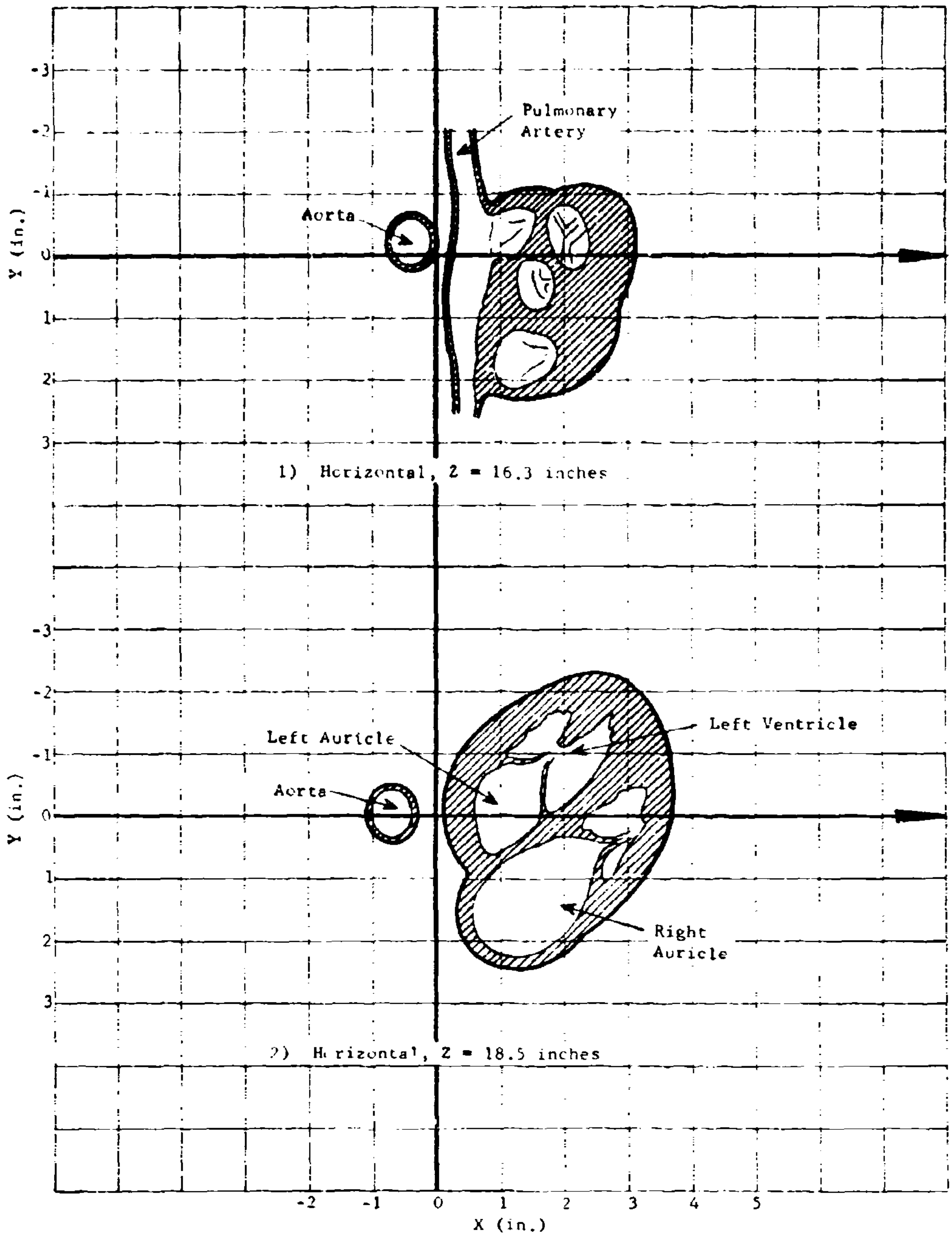


Figure 38 Sections of the Heart and Blood Vessels

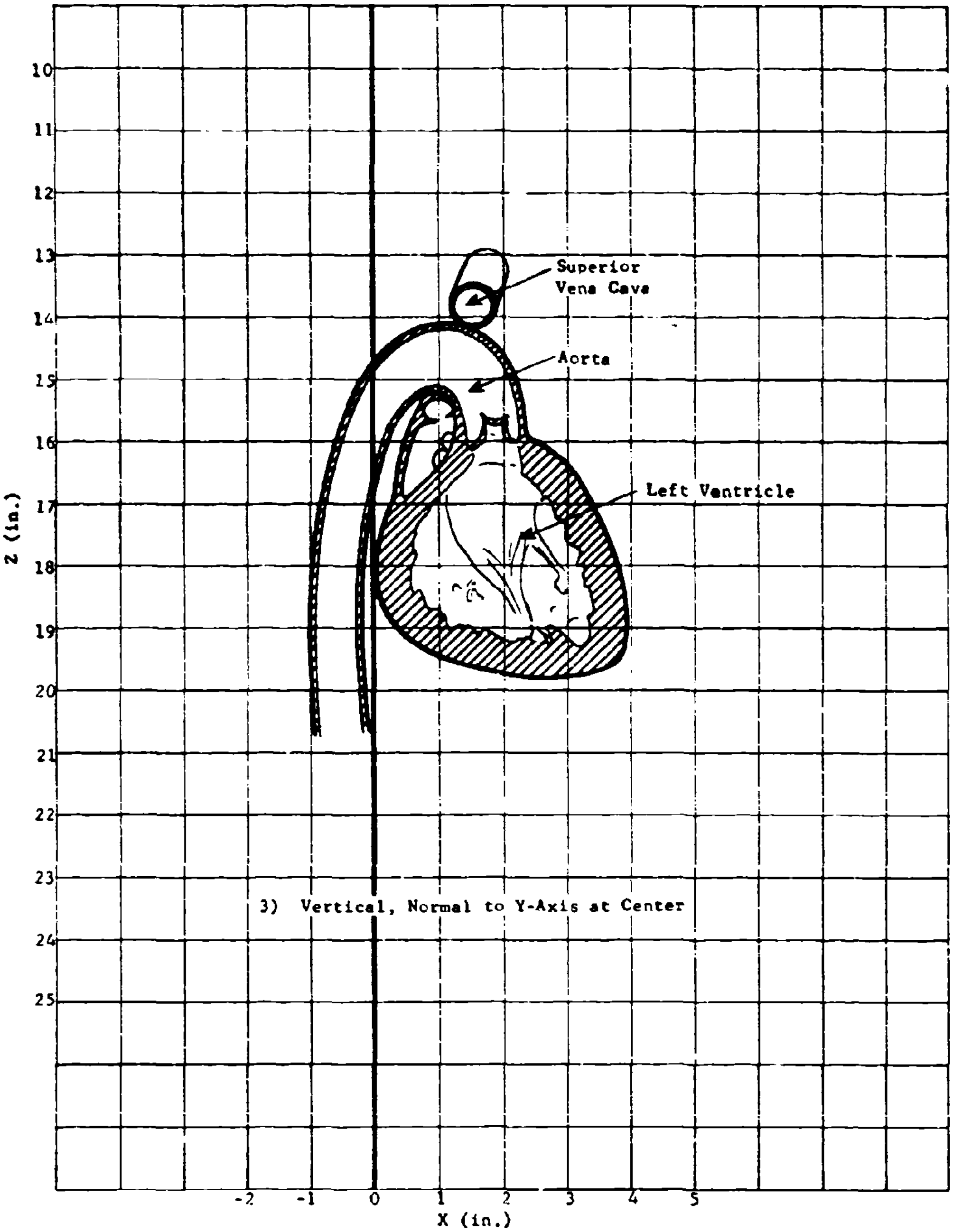


Figure 38 (cont)

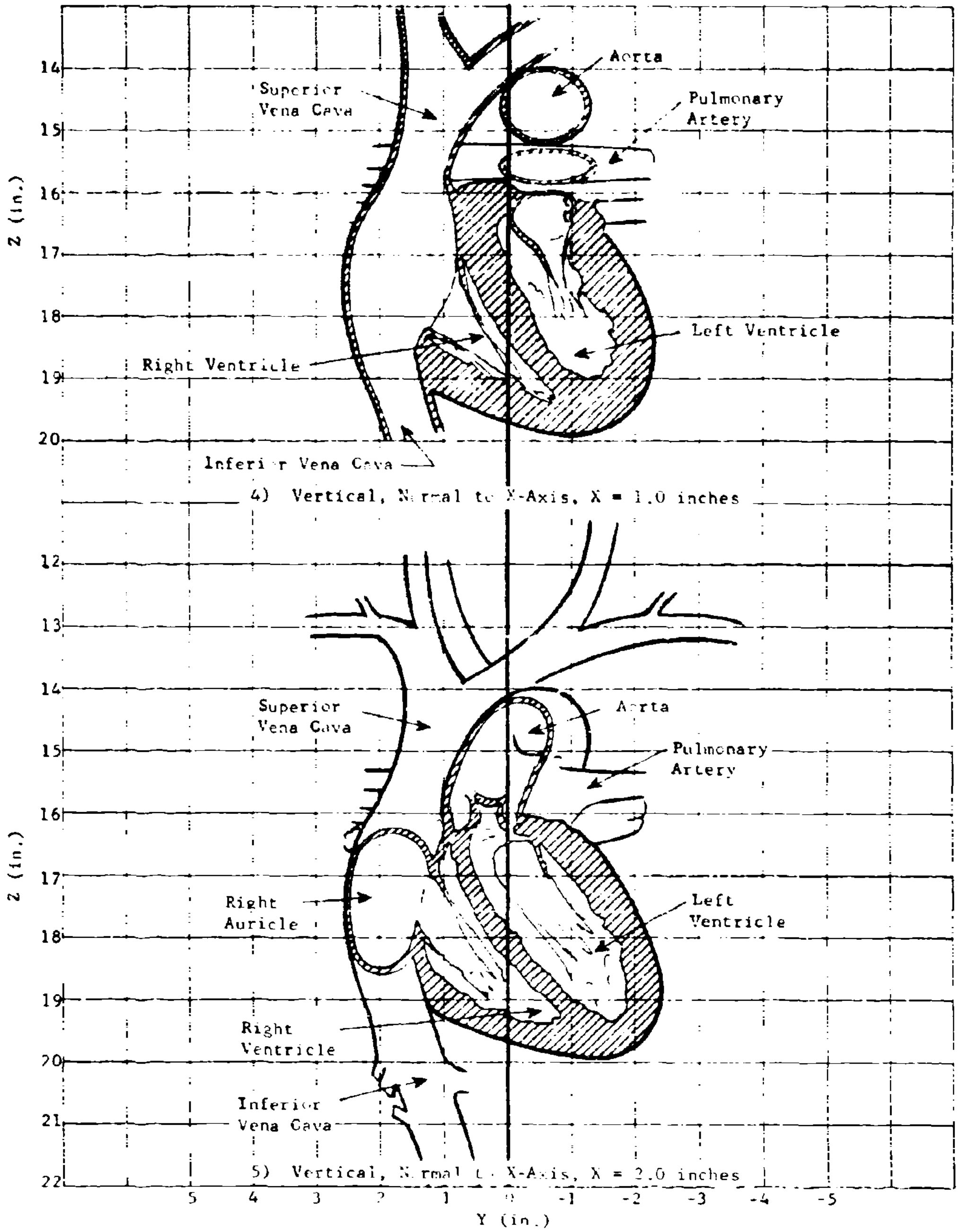
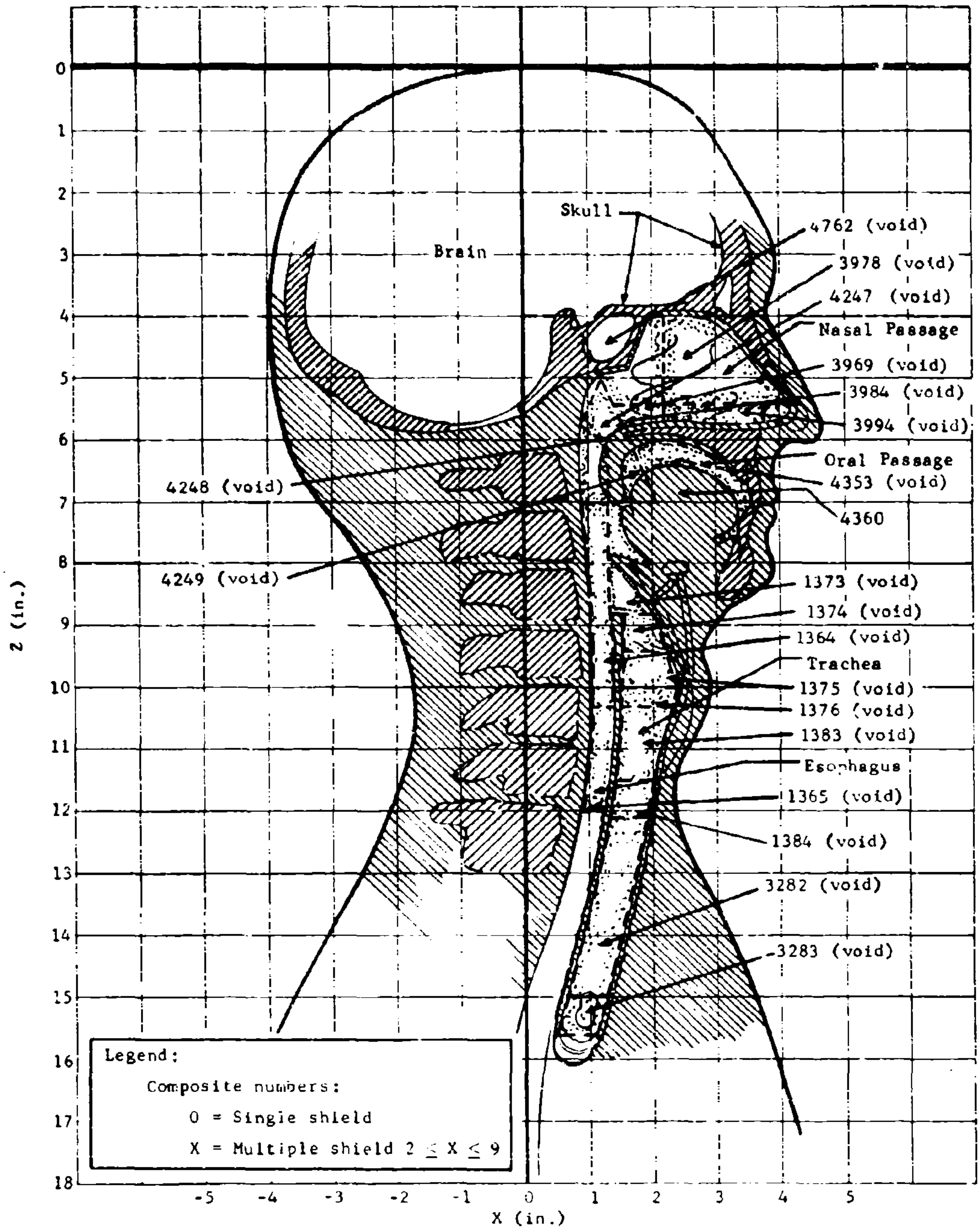
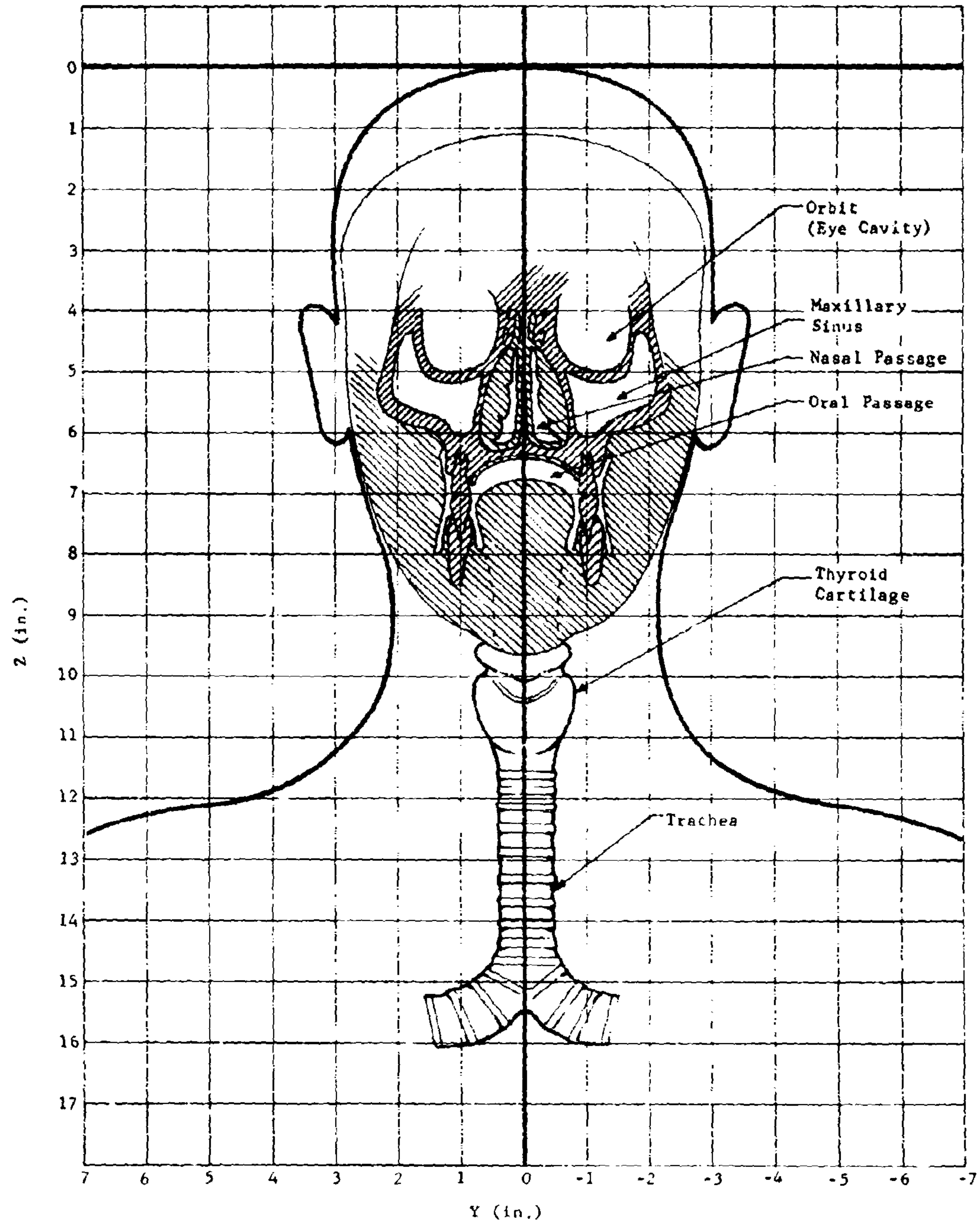


Figure 38 (concl)



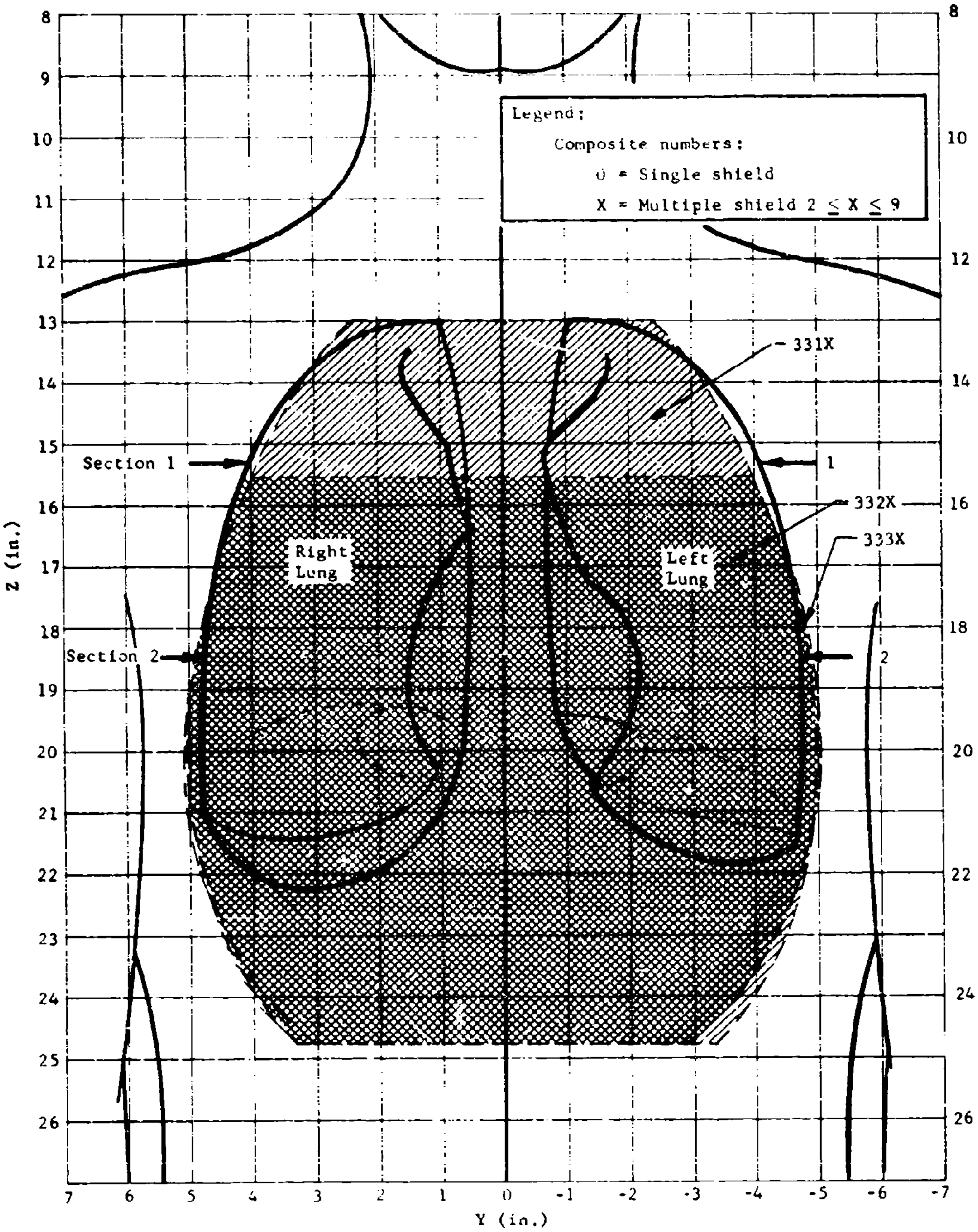
a. Vertical Section Normal to Y-Axis at the Center

Figure 39 Head with Nasal and Oral Passages, Esophagus, and Trachea



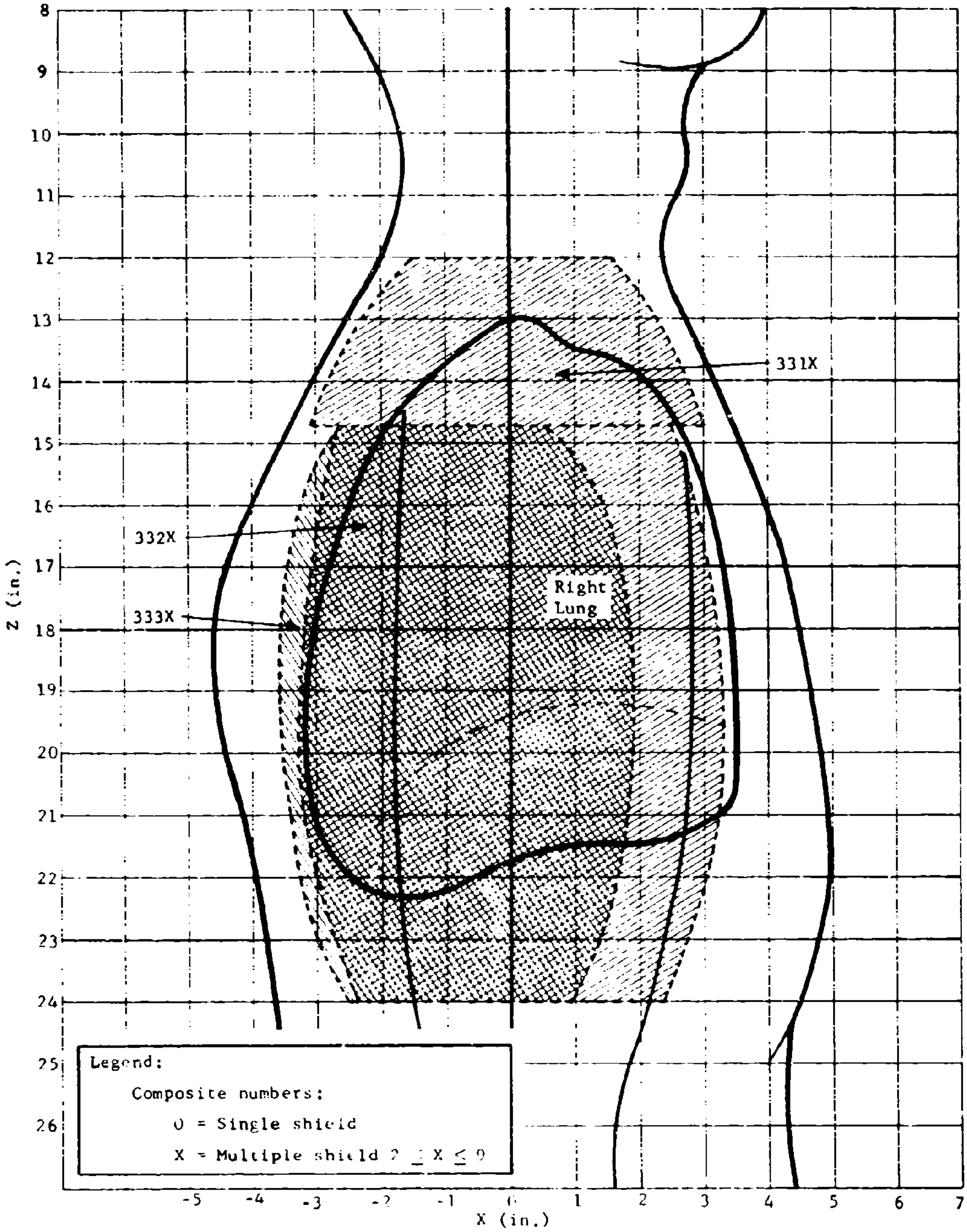
b. Vertical Section Normal to X-Axis at X = 2.7 inches

Figure 39 (concl)



a. Front View

Figure 40 Views of Lungs



b. Right Side View

Figure 40 (concl)

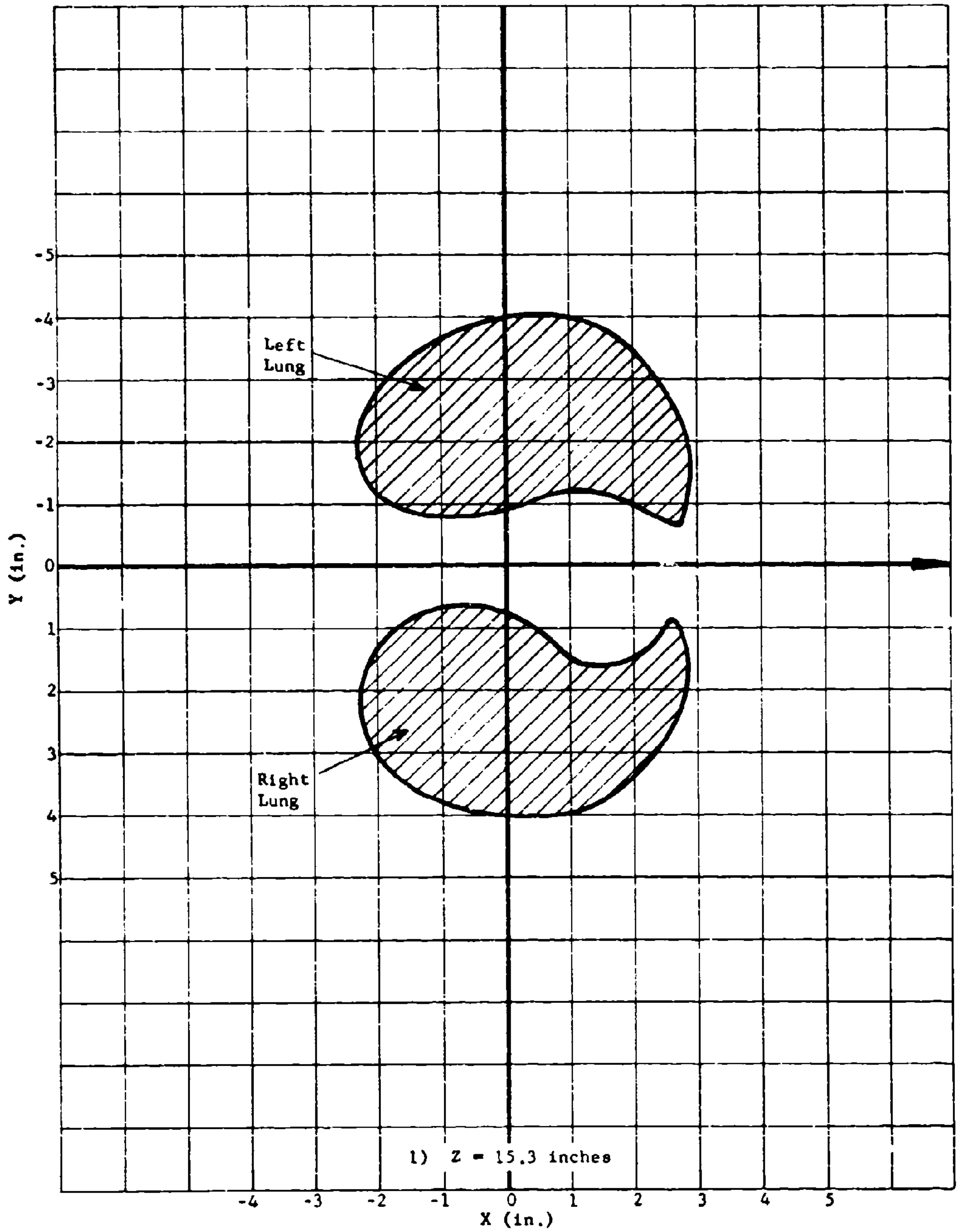


Figure 41 Horizontal Sections of the Lungs

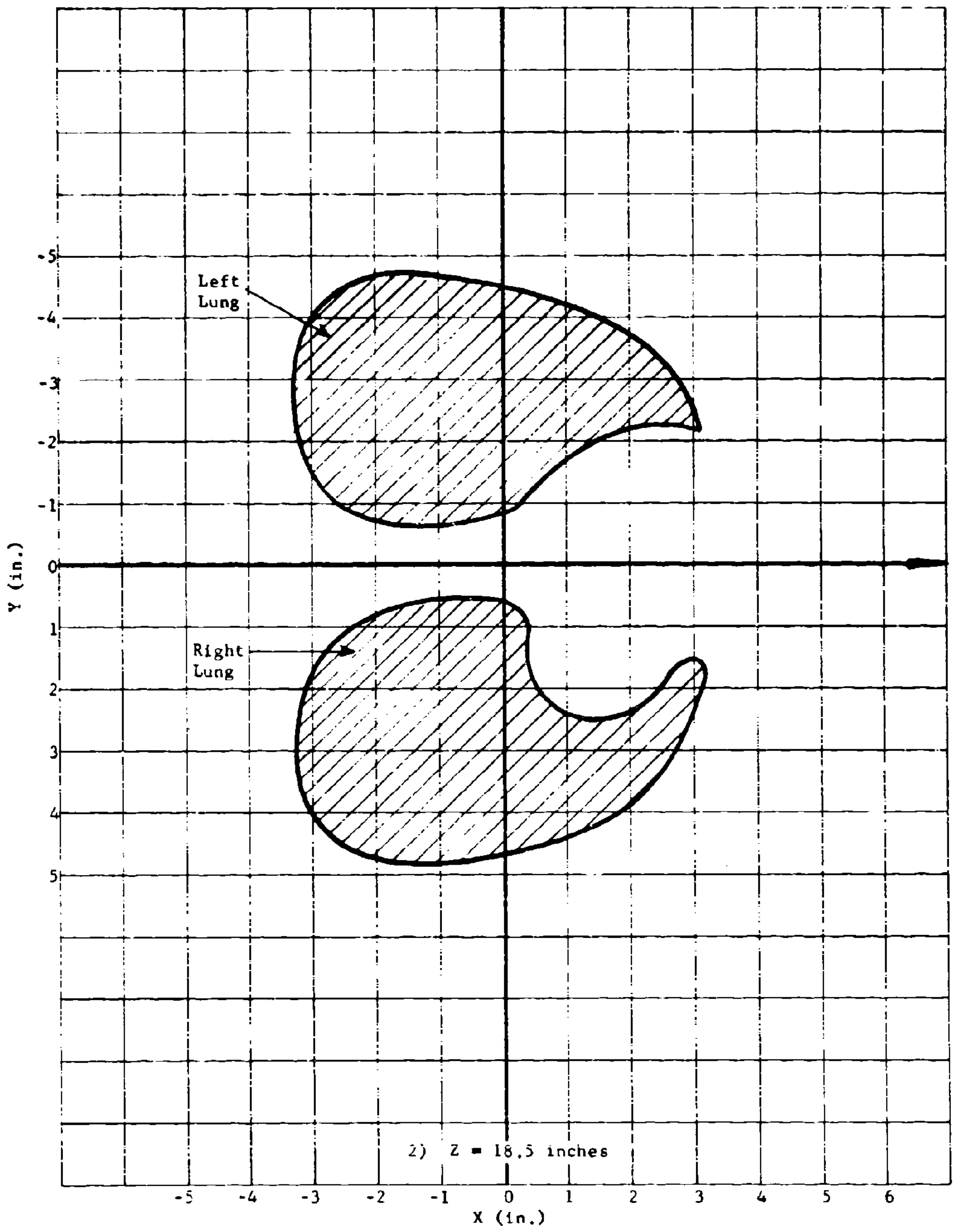
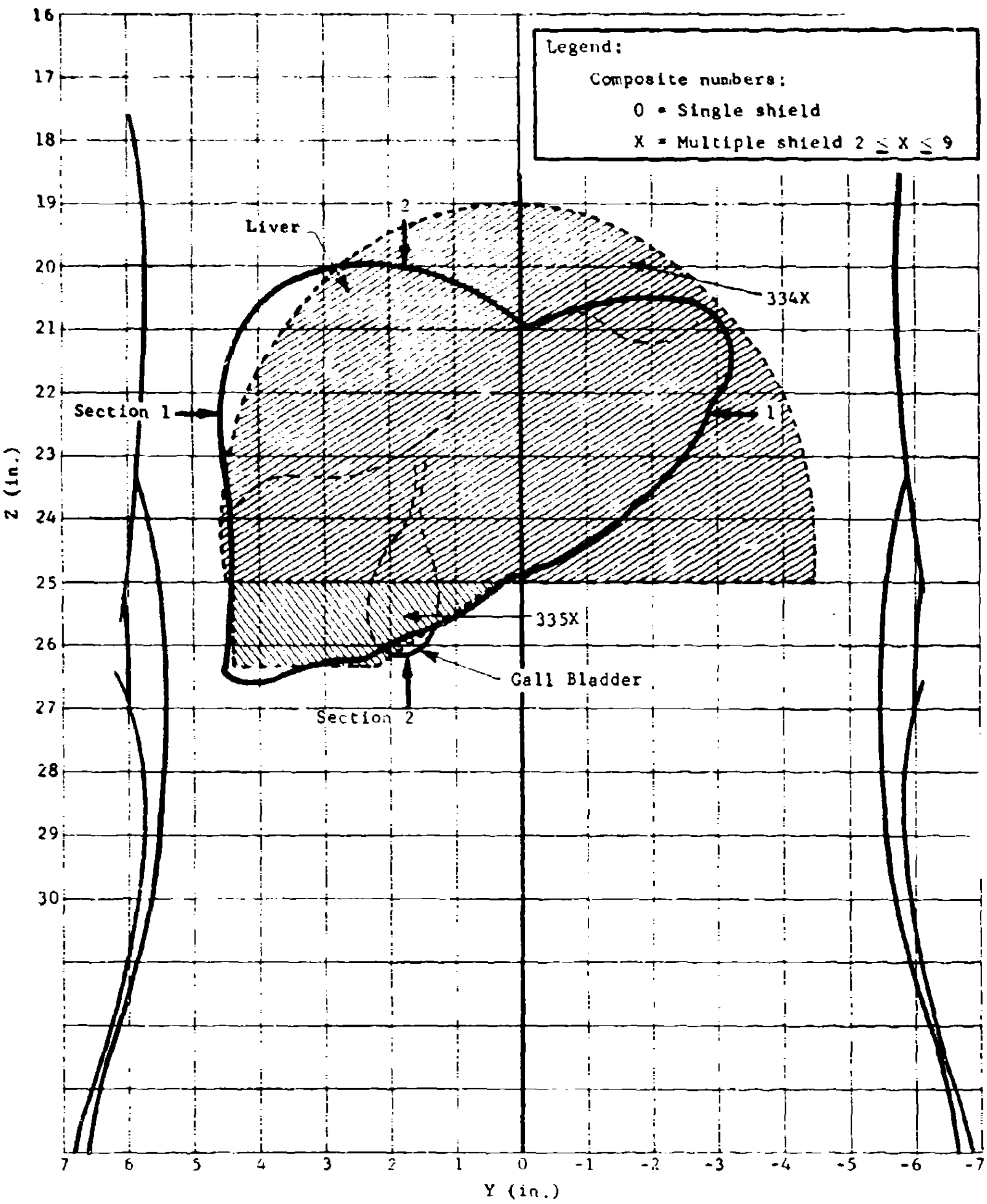
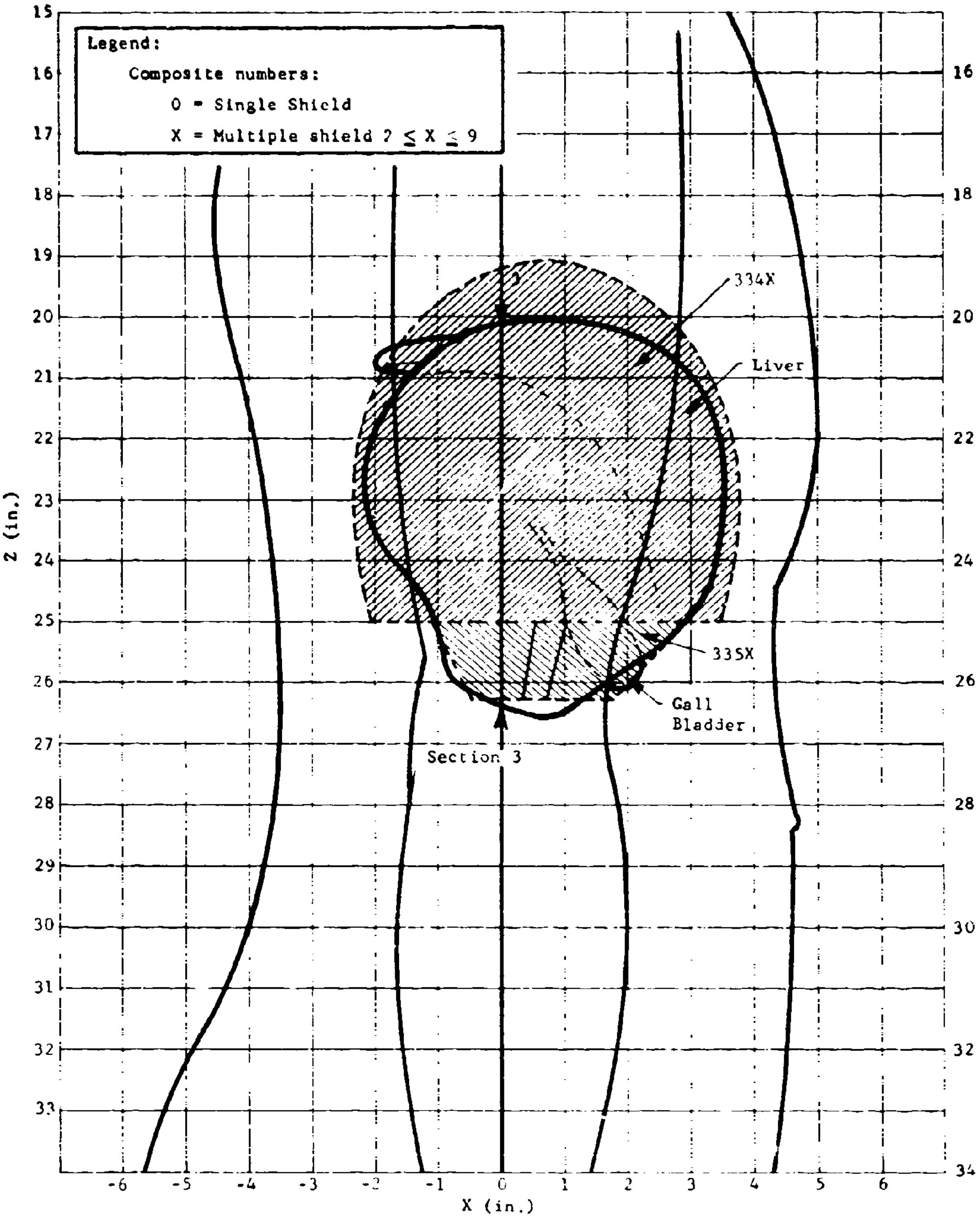


Figure 41 (concl)



a. Front View

Figure 42 Views of Liver and Gall Bladder



b. Right Side View

Figure 42 (concl)

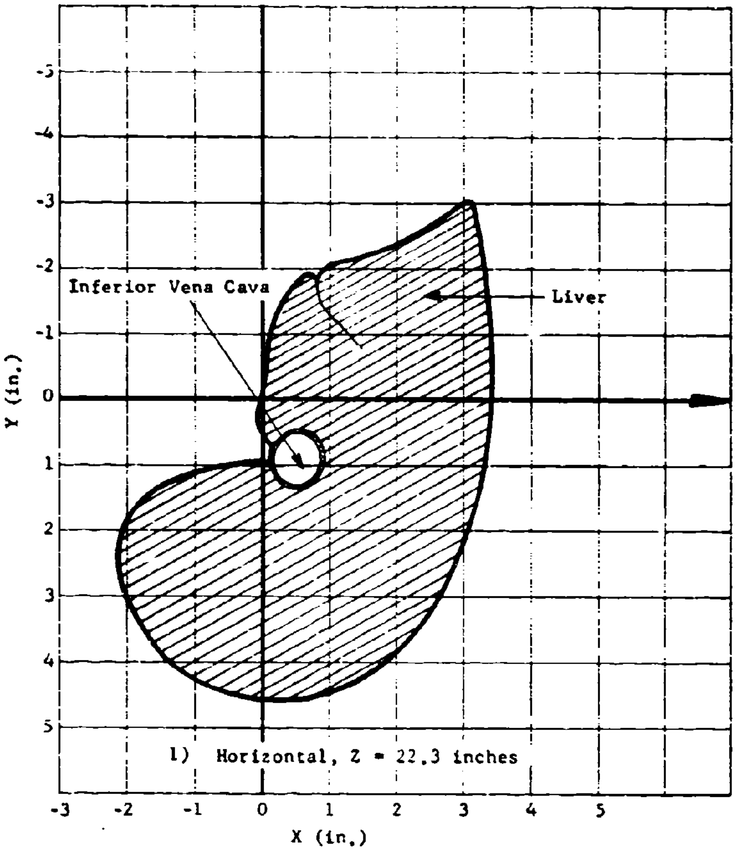


Figure 43 Sections of Liver and Gall Bladder

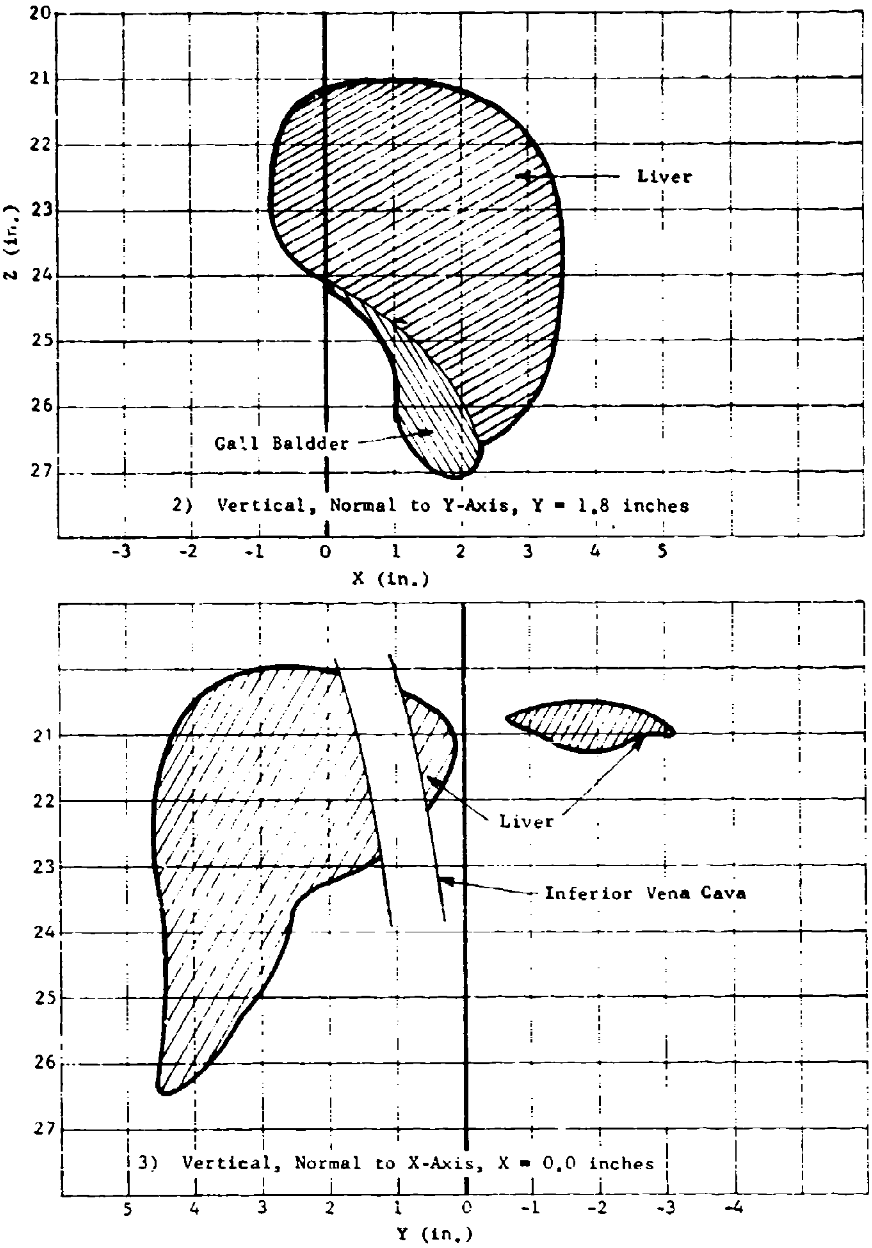
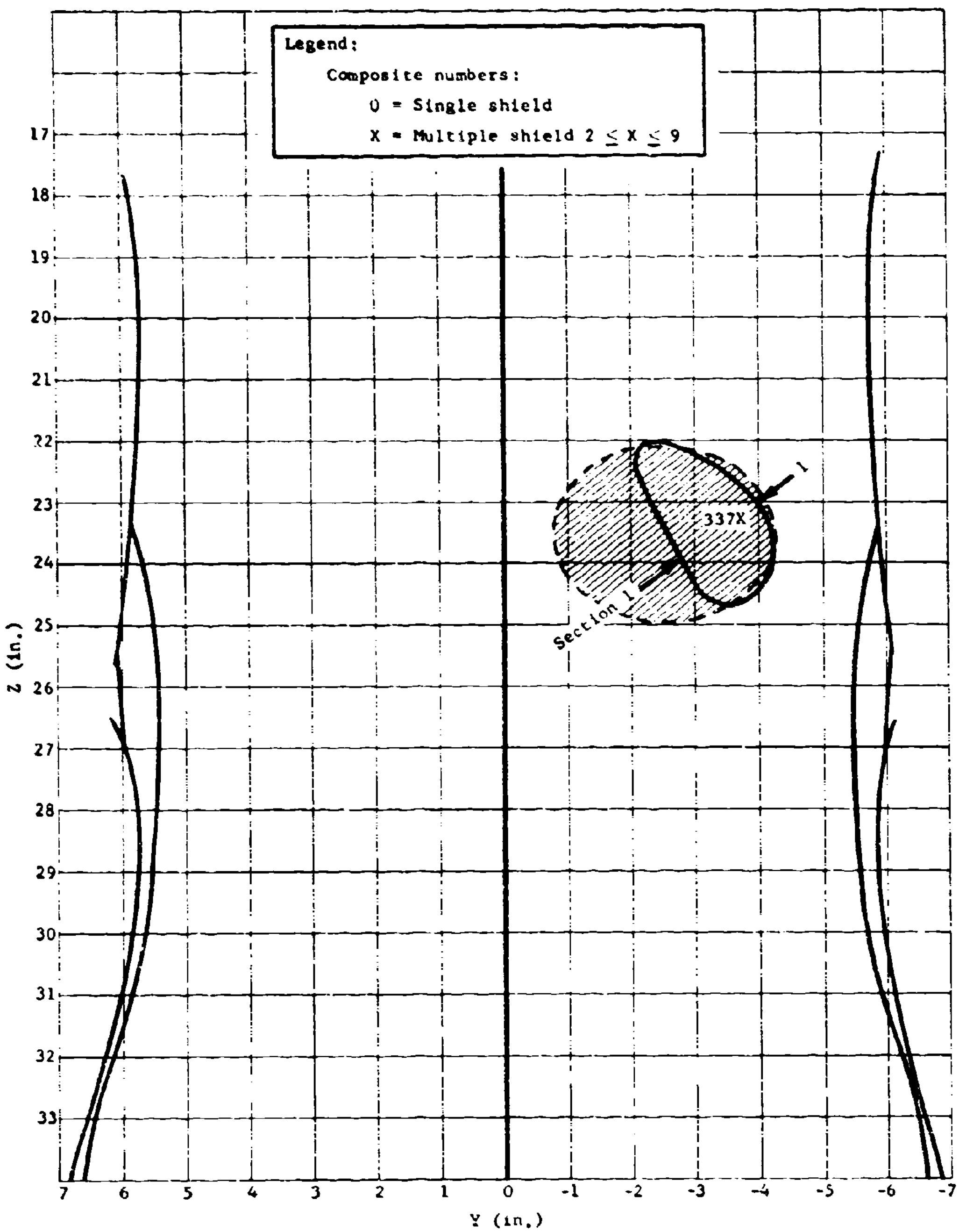
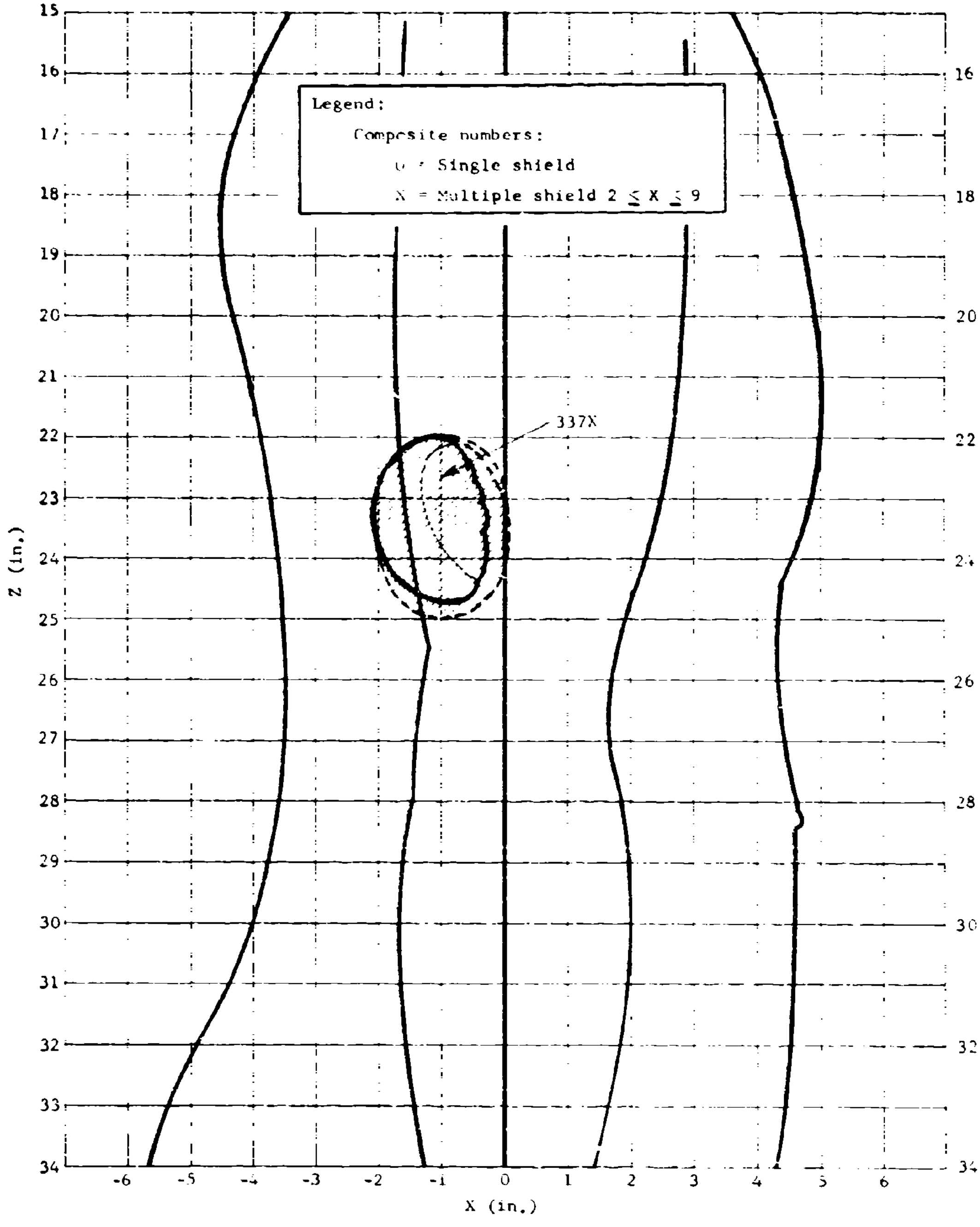


Figure 43 (concl)



a. Front View

Figure 44 Views of the Spleen



b. Right Side View

Figure 44 (concl)

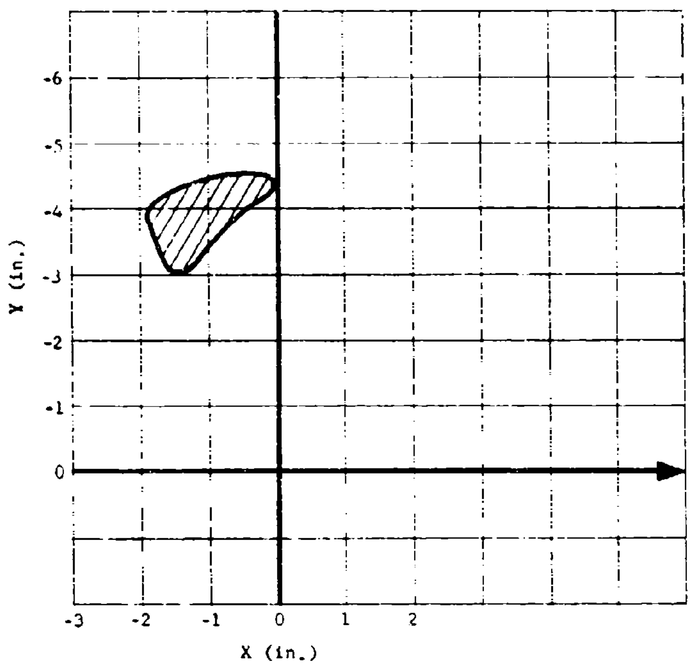
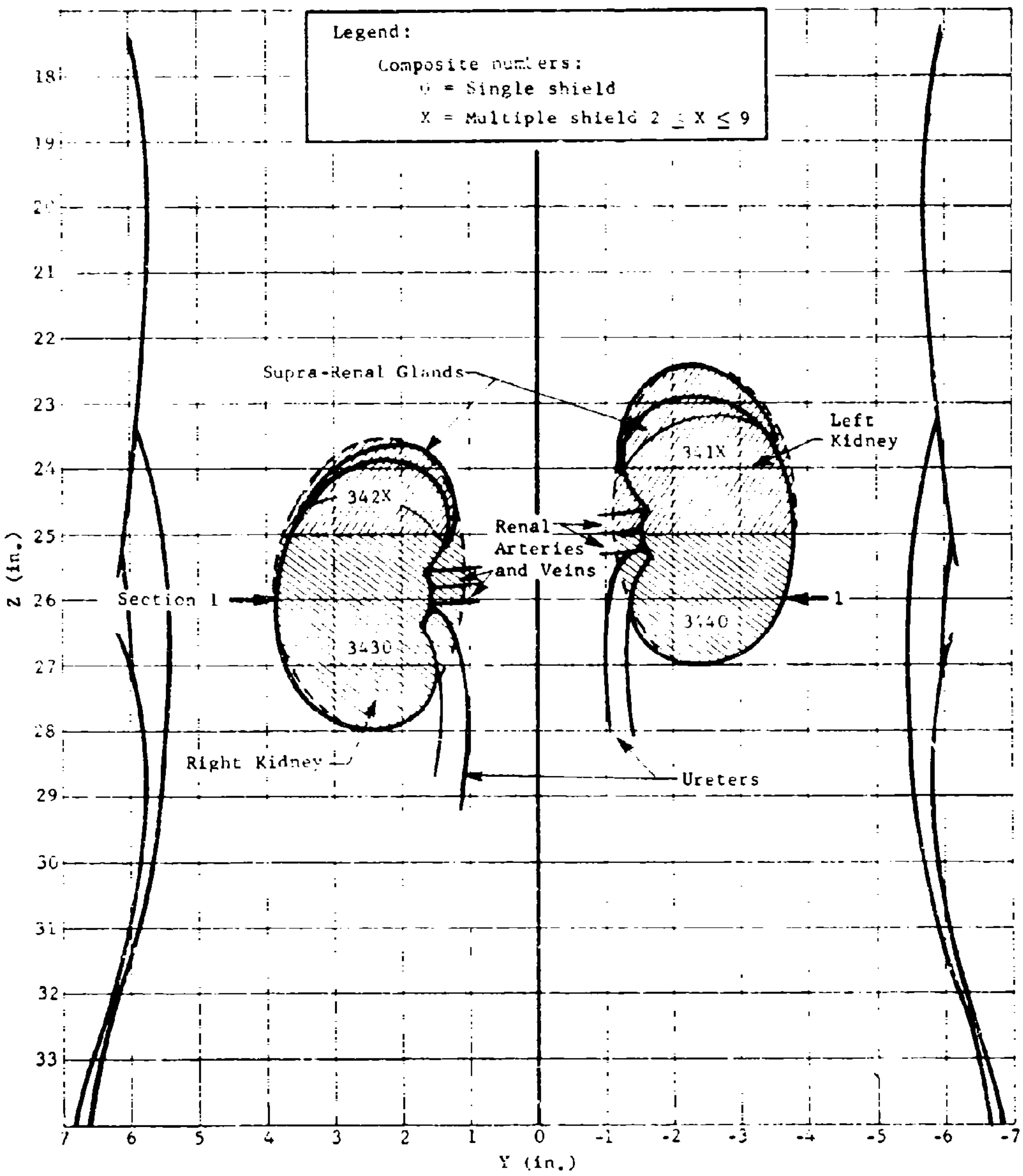
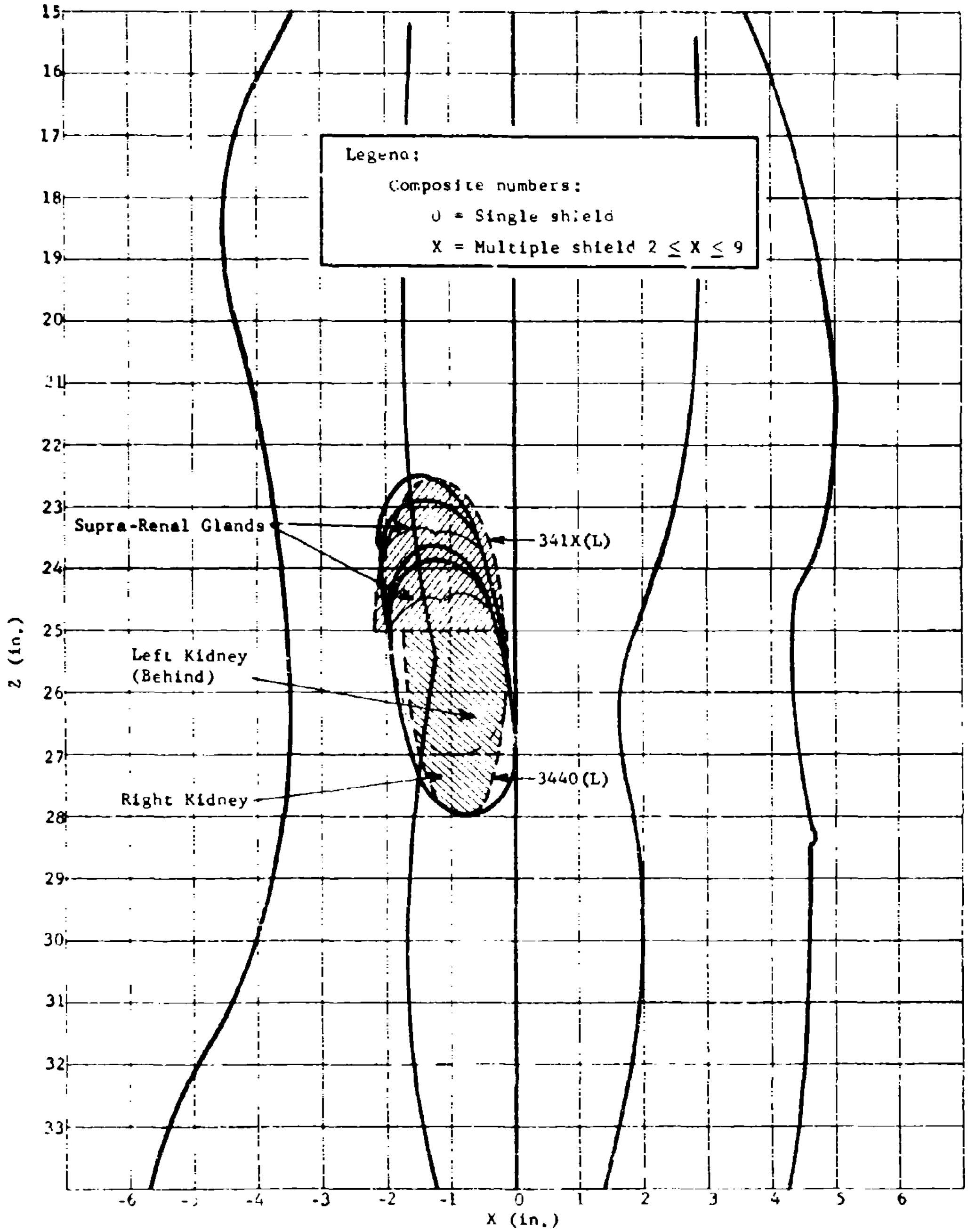


Figure 45 Transverse Section of the Spleen, 1)



a. Front View

Figure 46 Views of the Kidney and Adrenal Glands



b. Right Side View

Figure 46 (concl)

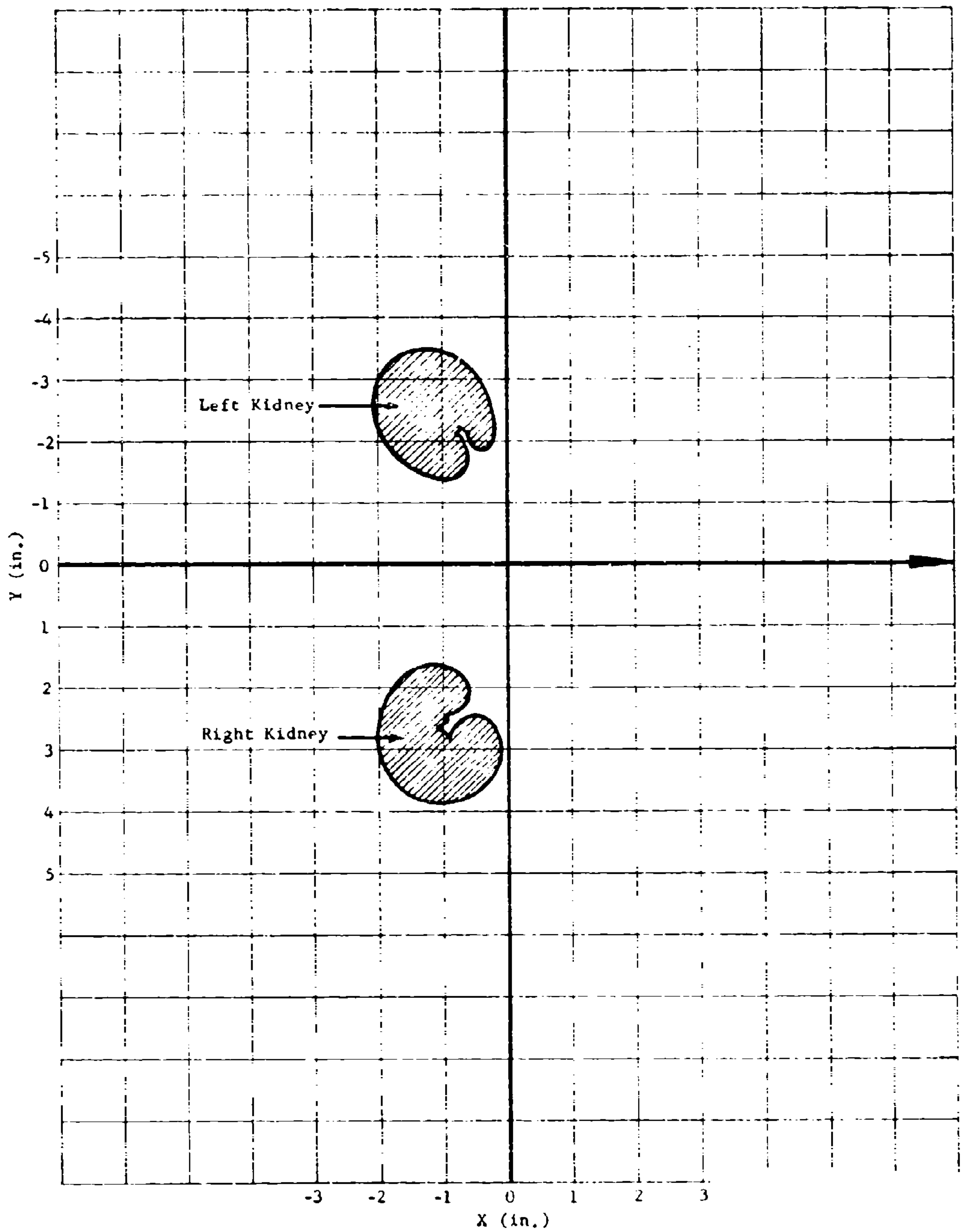
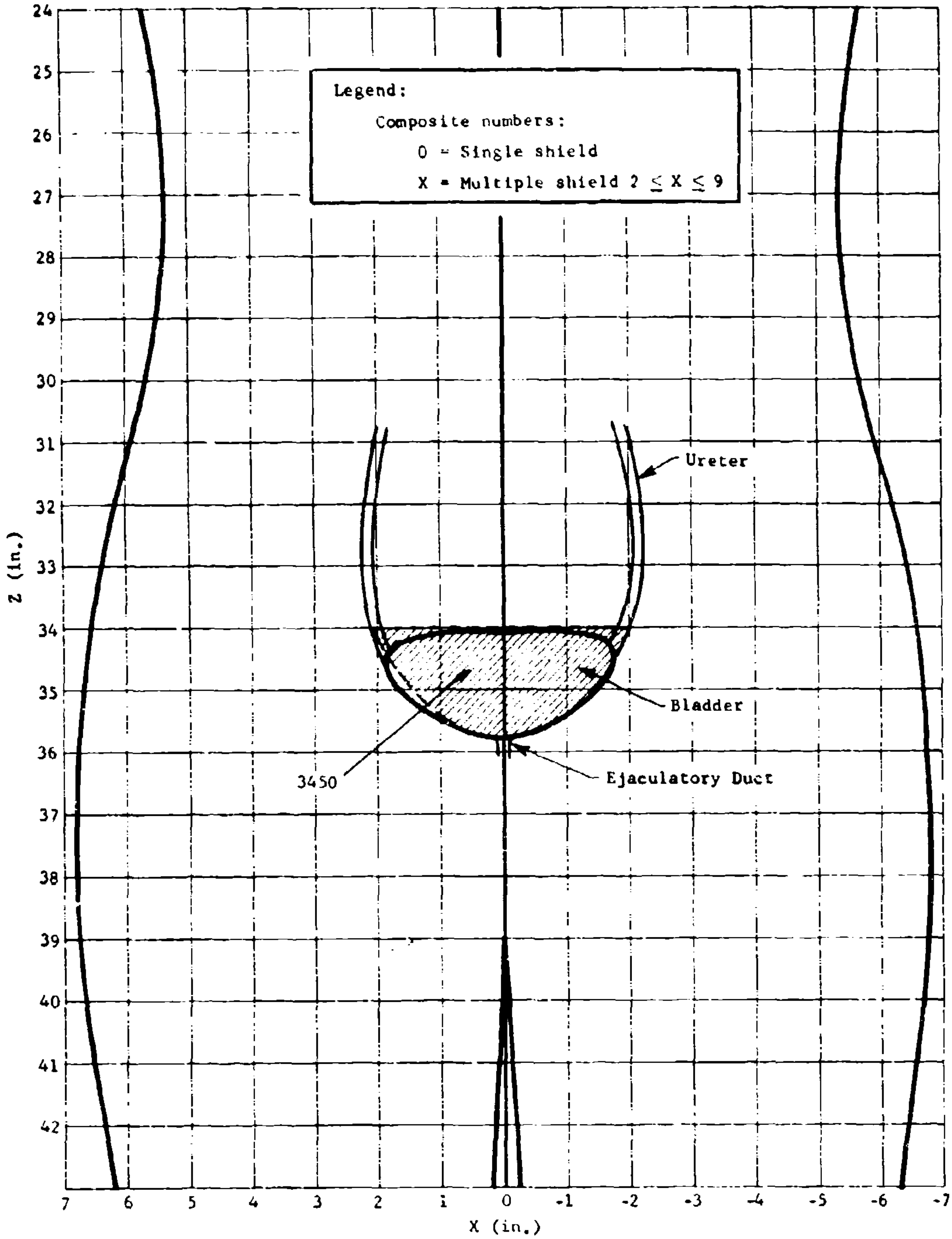
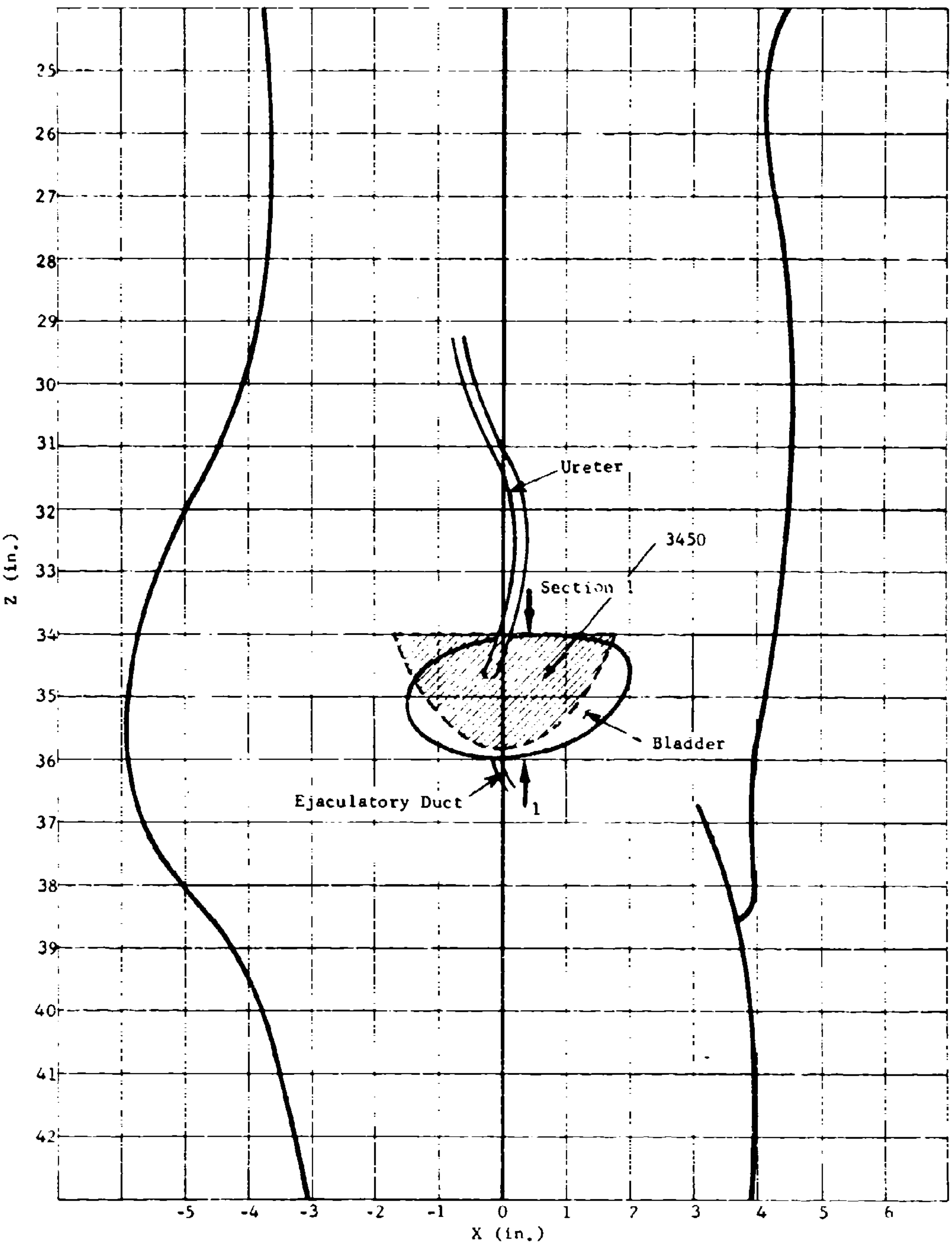


Figure 47 Horizontal Section of the Kidneys, Z = 26.0 inches, 1)



a. Front View

Figure 48 Views of the Bladder



b. Right Side View
Figure 48 (concl)

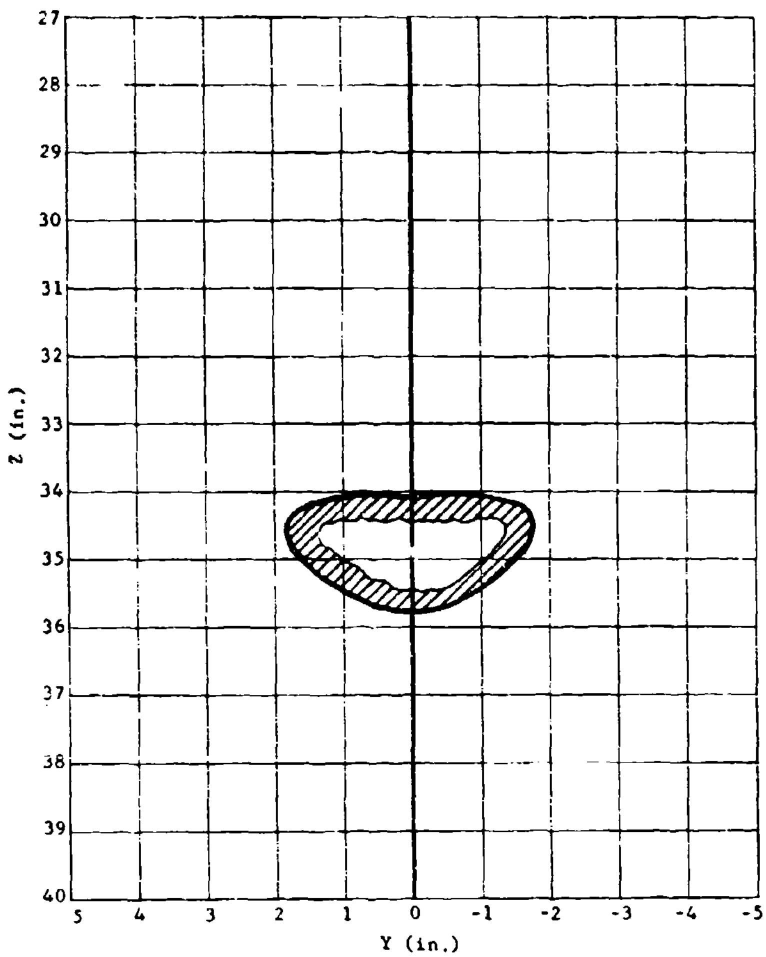
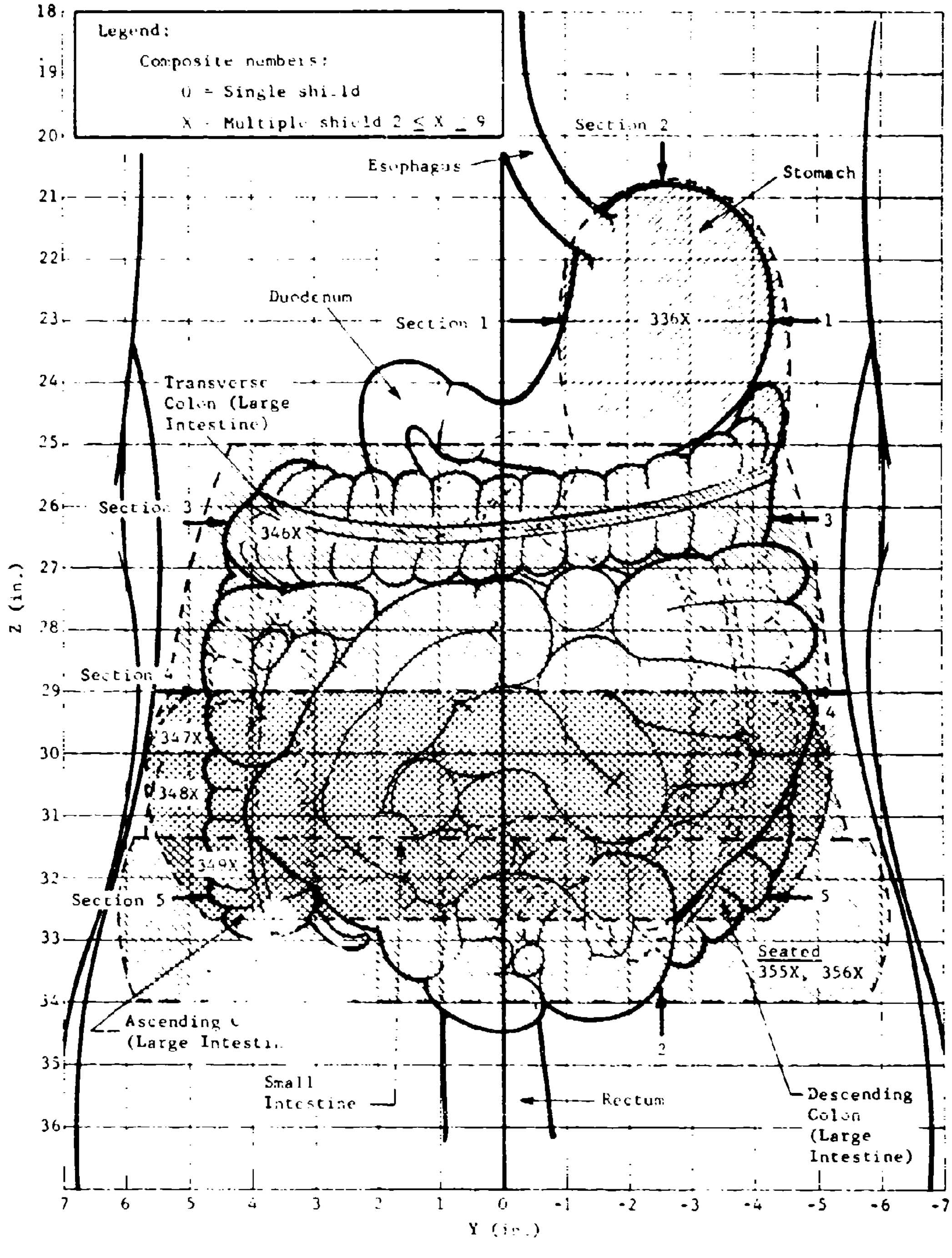
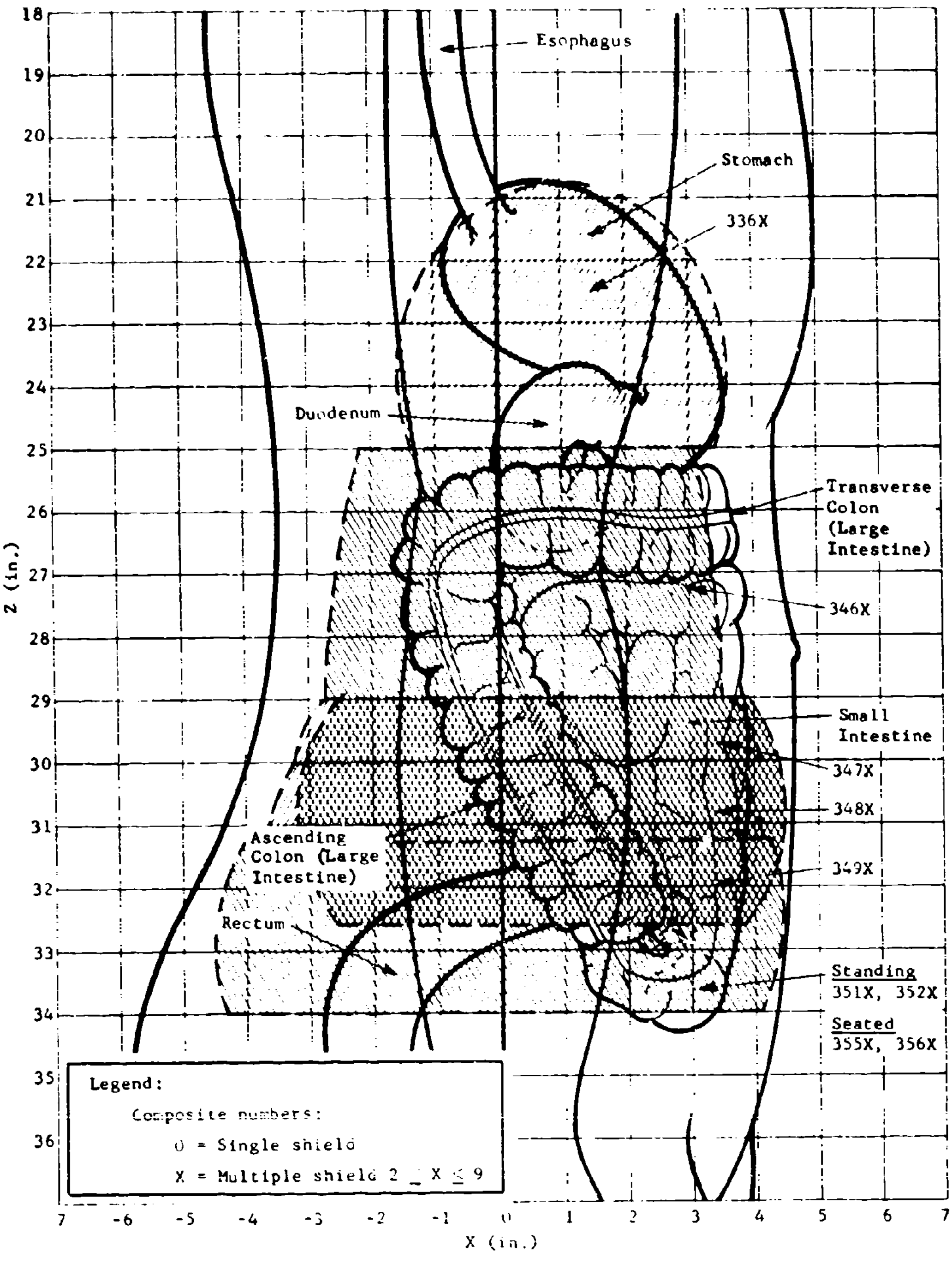


Figure 49 Vertical Section of the Bladder, Normal to the X-Axis, X = 0.3 inches, 1)



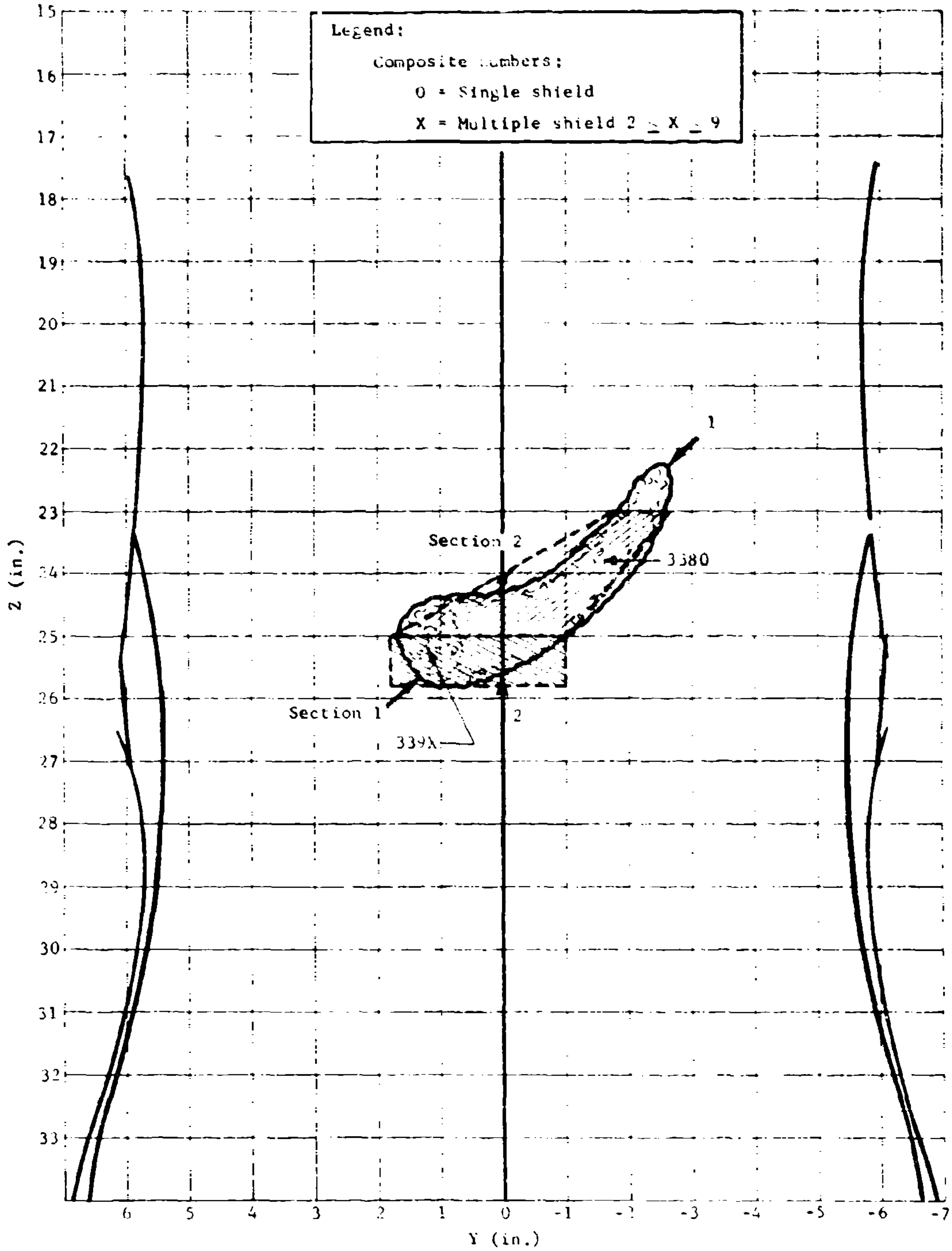
a. Front View

Figure 50 Views of the Gastrointestinal Tract



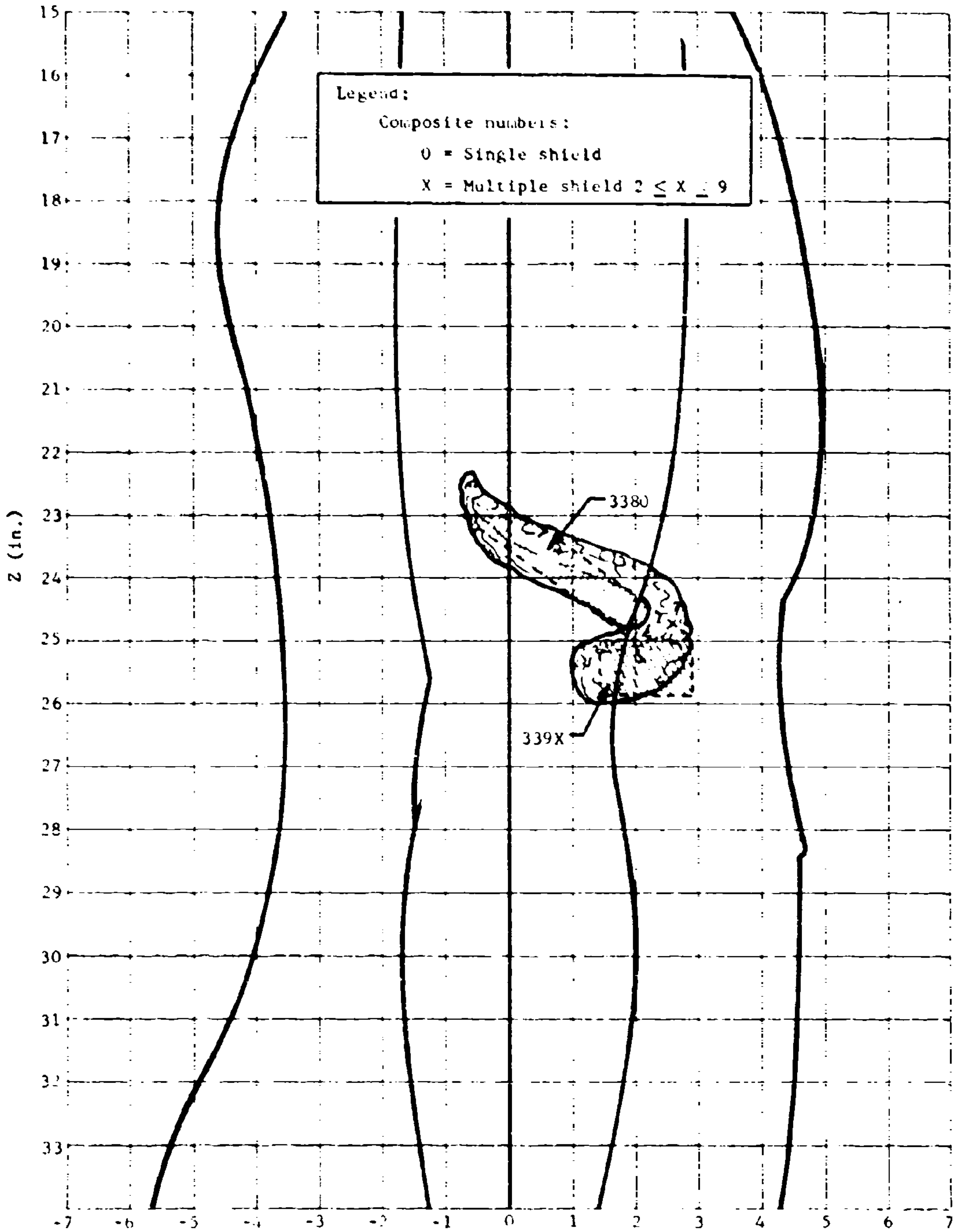
b. Right Side View

Figure 59 (concl)



a. Front View

Figure 51 Views of the Pancreas



b. Right Side View

Figure 51 (concl)

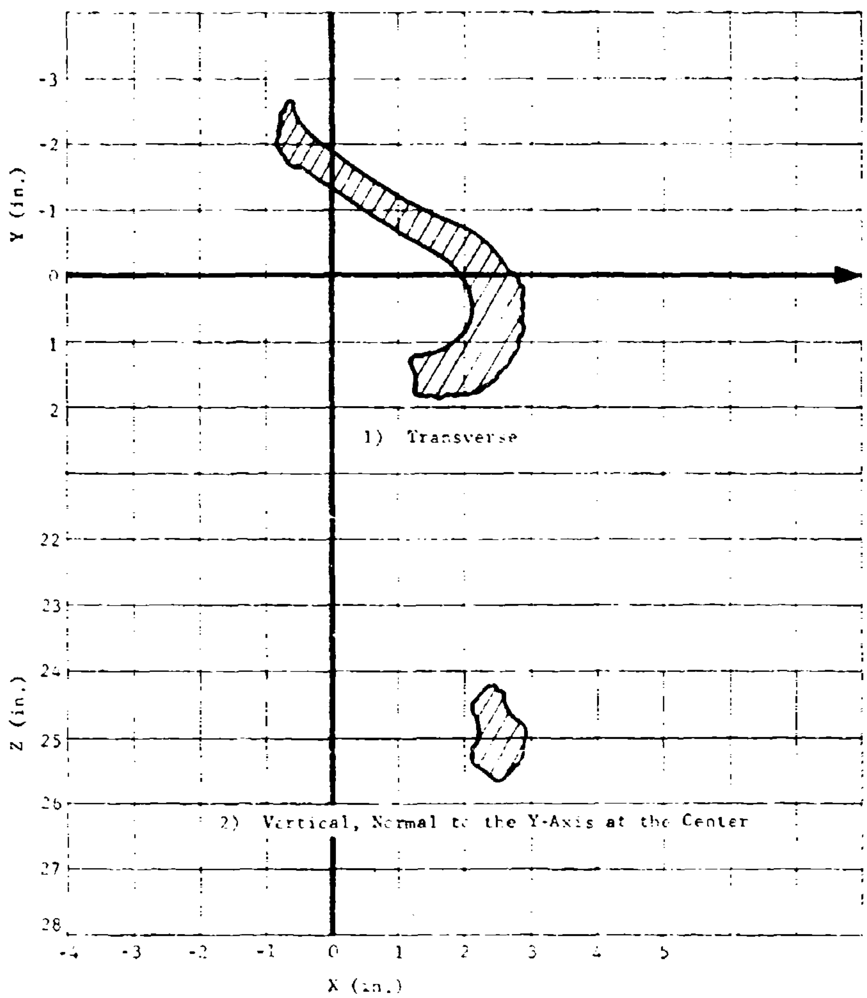


Figure 52 Sections of the Pancreas

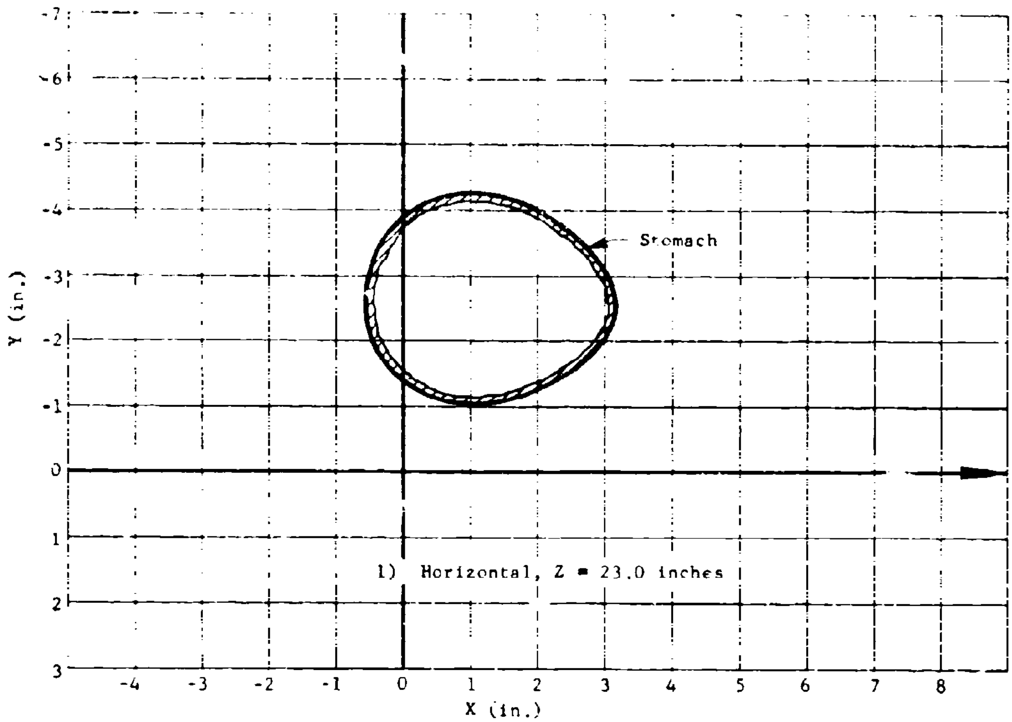


Figure 53 Sections of the Stomach and Intestines

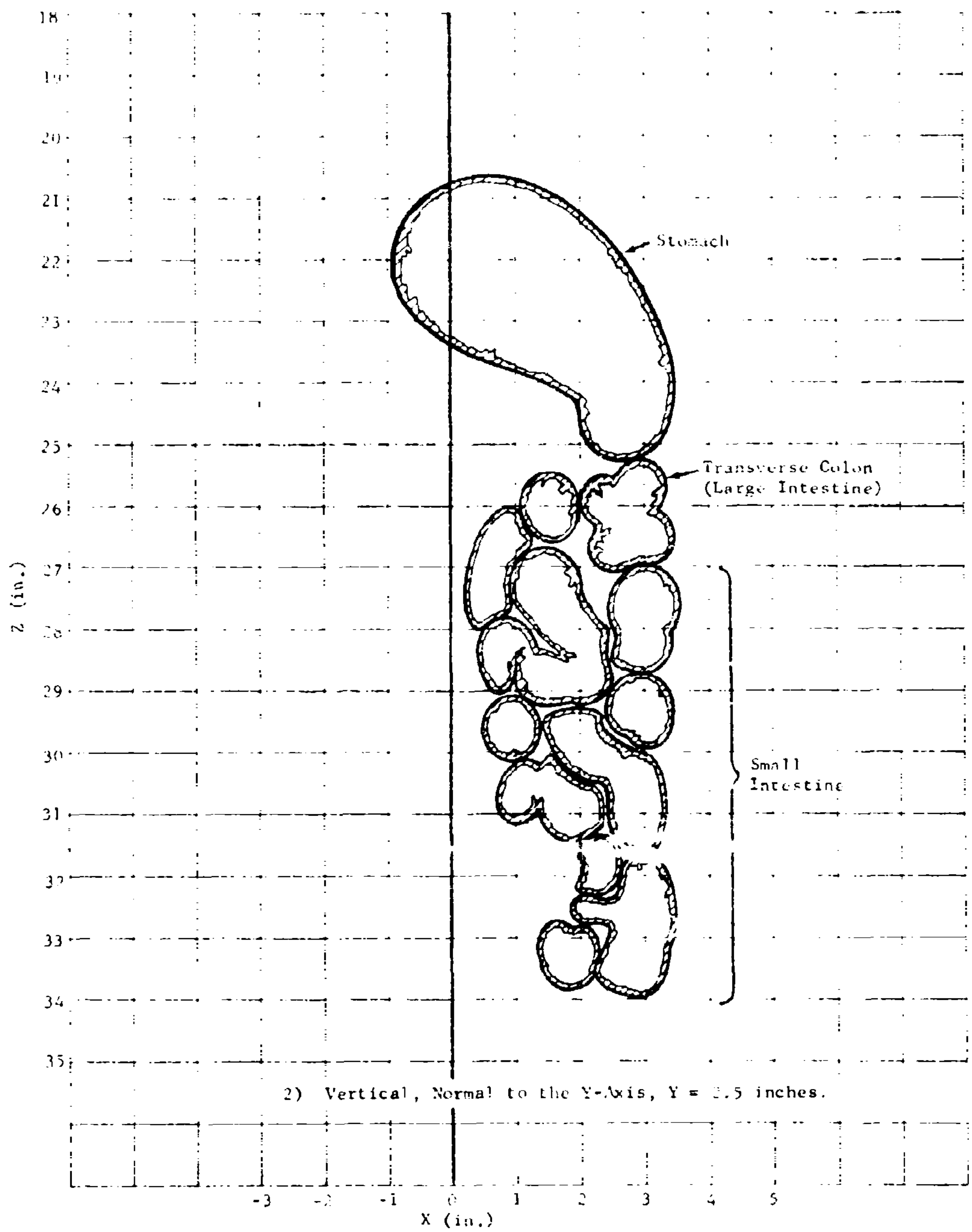


Figure 53 (cont)

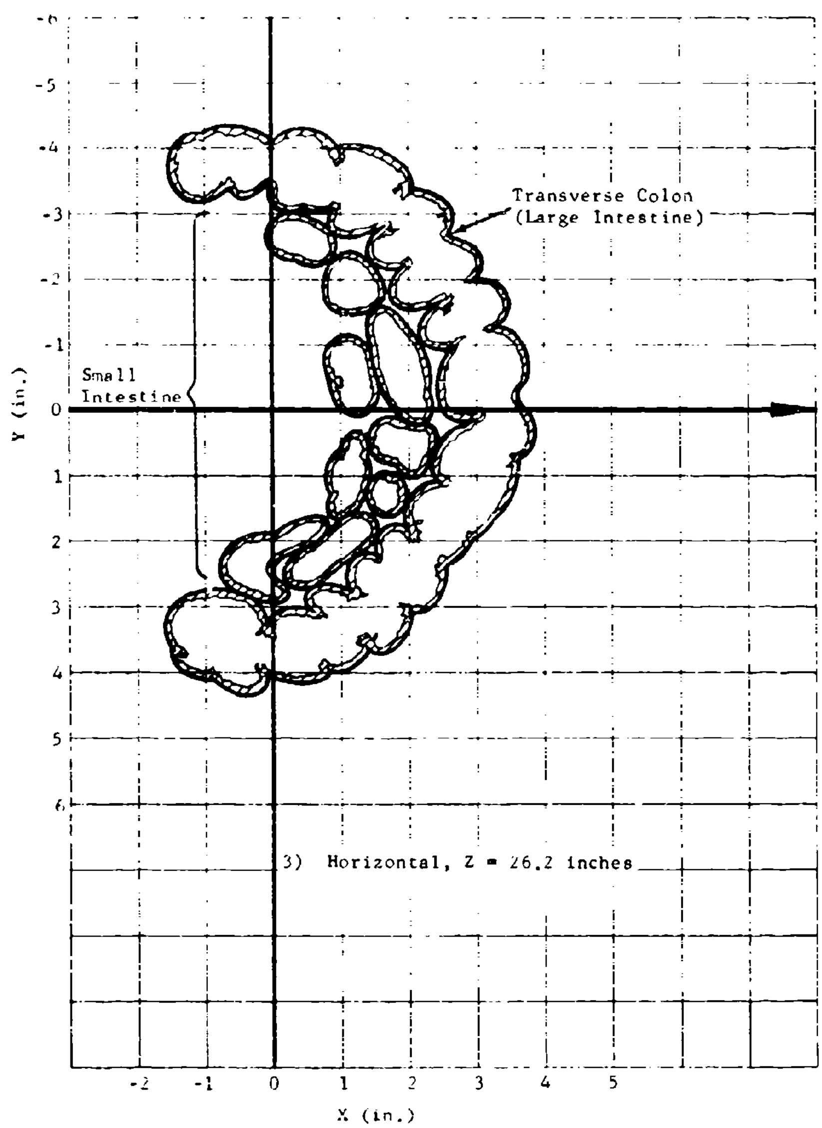


Figure 53 (cont)

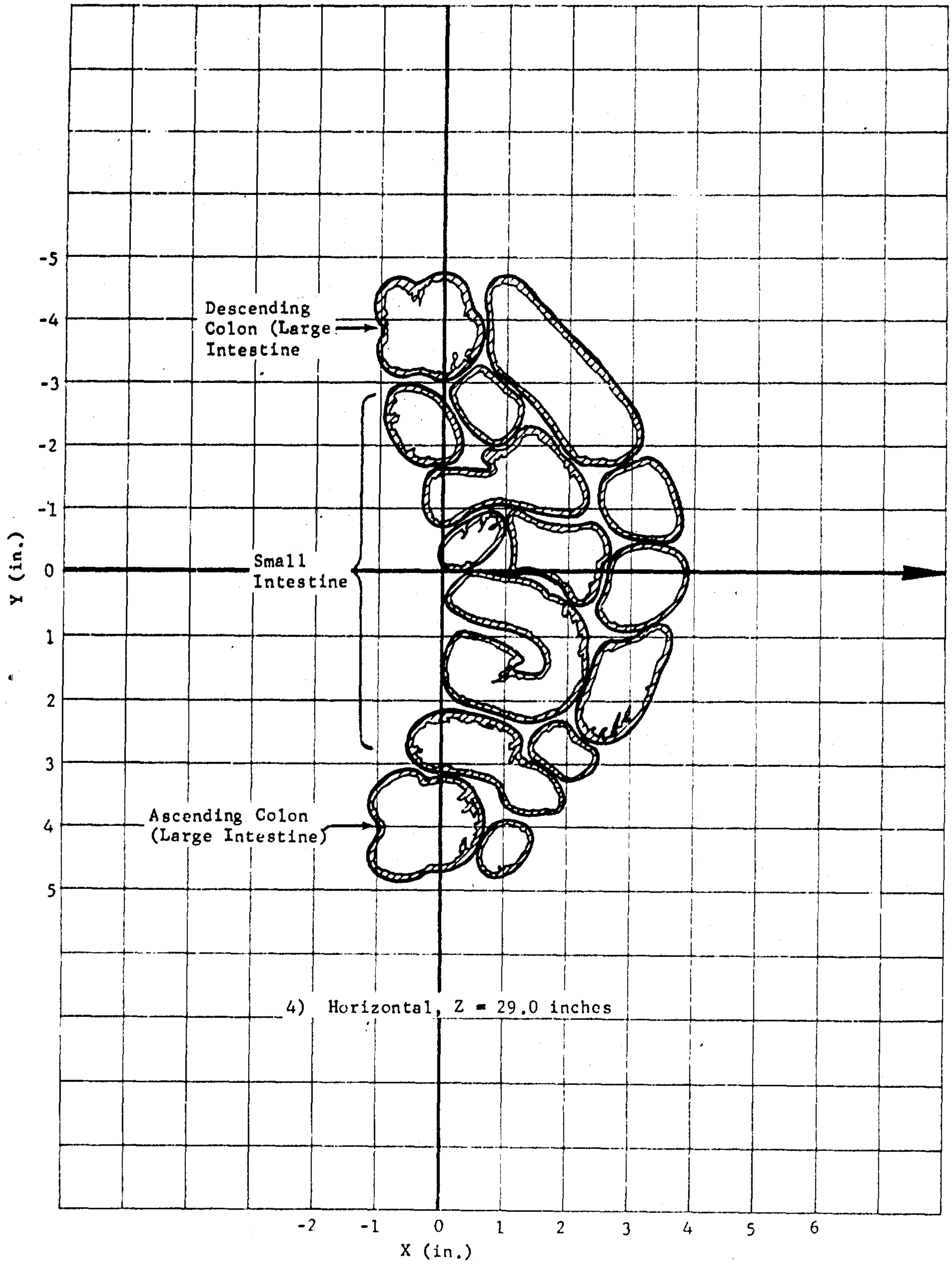


Figure 53 (Cont)

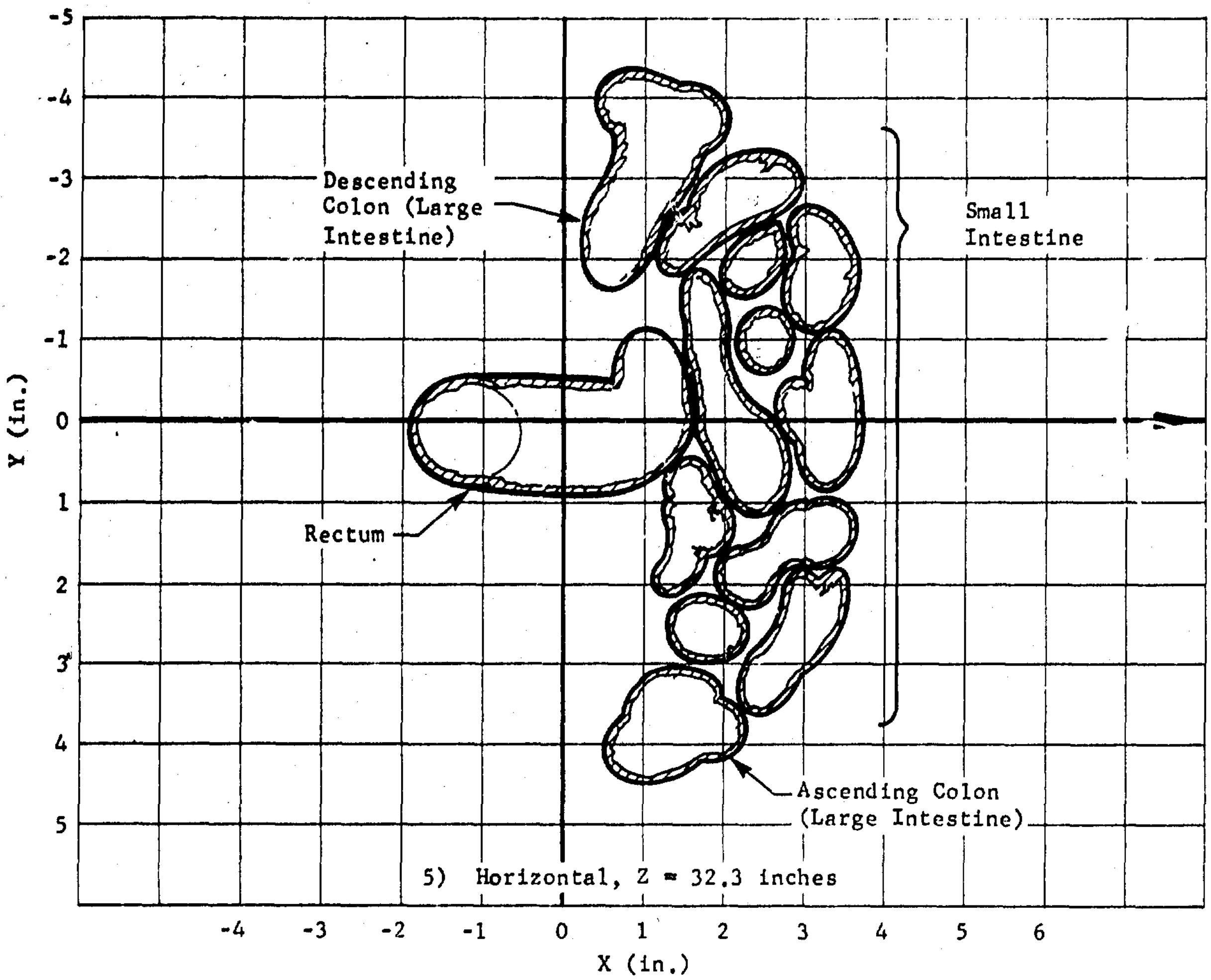


Figure 53 (concl)

APPENDIX II

LISTING OF CARD DECKS FOR THE MODEL

1. CARD FORMATS

The partial listing that follows is for the Computerized Anatomical Model Man only. None of the other input necessary for running MEVDP is shown.

It is noted that only two types of card formats are used. The first type contains a mixture of identification, material, and dimensional data. The second type contains only the XYZ locations of the points indicated in Figure 12, 2 points per card. Depending on the geometrical shape under consideration, up to 4 cards of the second type are required. A set of first and second type cards is used to describe each geometrical shape of the model.

The requirements for the first data card are given in Table X. The entries on this card include the following:

1) Shield Serial Number - The 4-digit shield identification system was explained in Section III, Description of the Model. The data is in integer form.

2) Shield Type - Each of the seven compatible geometrical shapes is identified as a solid by an odd integer, or as a void by an even integer, according to the tabulation.

Type of Shield	Void	Solid
Hexahedron	0	1
Cylinder	2	3
Sphere	4	5
Hemisphere	6	7
Cone	8	9
Truncated cone	10	11
Ellipsoid	12	13

The first shield of a composite is always a solid. In this model only one solid is used in a composite. The second and succeeding shields in the composite are always voids.

Table X. Data Requirements, First Card of Set

Columns	1	2 - 5	6, 7	8 - 10	11 - 20	21 - 30	31 - 35	36 - 40	76 - 79	80
	Blank	Shield serial no.	Shield type	Material code	Cylinder radius (in.) or cone half-angle (radians)	Density of material (gm/cm^3)	No. of coordinates for ellipsoids	No. of shields in composite	Shield serial no.	Card no.
		A	A	A	B C	B	A D	A E	A F	

A - Integer, right-adjusted, see Appendix II.
B - Left-adjusted with decimal, not exponential format.
C - Columns 11 through 20 are left blank for hexahedrons, spheres, hemispheres, and ellipsoids.
D - Blank if shield is not an ellipsoid; if the shield is an ellipsoid, see Appendix II.
E - Equal to one if shield is not part of a composite; if a composite, enter the total number on the first card of the first shield. Leave this column blank for the remaining shields.
F - This is for identification only. It is ignored during processing.

3) Material Code - The chemical composition of the material is defined by an integer of up to 3 digits. The code numbers for the Computerized Anatomical Model Man are given in Table VI.

4) Cylinder Radius or Cone Half Angle - These dimensions are shown in Figure 12. The data is entered in decimal, not exponential format.

5) Density of Material - The material densities are associated with the material code numbers of the model in Table VI. These data are entered in decimal format only.

6) Number of Coordinates for Ellipsoids - This entry is an integer, selected as appropriate from the following list:

   4 Nontruncated

   +5 Single truncation with lower portion eliminated with respect to Z_E axis (See Table XI)

   -5 Single truncation with upper portion eliminated with respect to $+Z_E$ axis (See Table XI)

   6 Double truncation.

7) Number of Shields in Composite - If the shield is not a composite, the entry is the integer 1; if the shield is a composite, the appropriate integer, 2 through 9, is entered on the first data card for the composite. There is no entry on the remaining card sets of the composite.

8) Shield Serial Number and Card Number - This information appears on every data card. It is for identification only and is ignored by the computer during processing of a problem.

The requirements for the second, and subsequent cards if needed, of a shield data set are shown in Table XI. The required number of cards of this type are summarized below:

Geometrical Shape	Number of Type 2 Cards
Hexahedron	4
Cylinder	1
Sphere	1
Hemisphere	1
Cone	1
Truncated cone	2
Ellipsoid	2 or 3

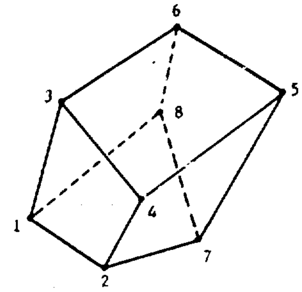
Table XI. Data Requirements, Second and Succeeding Cards of Set

Hexahedrons, Type 0 (Void), 1 (Solid)

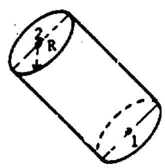
8 Points Required, Ordered as Shown

Columns	1-10	11-20	21-30	31-40	41-50	51-60	76 - 79	80
Card 2	X_1	Y_1	Z_1	X_2	Y_2	Z_2	Same as Card 1	2
Card 3	X_3	Y_3	Z_3	X_4	Y_4	Z_4		3
Card 4	X_5	Y_5	Z_5	X_6	Y_6	Z_6		4
Card 5	X_7	Y_7	Z_7	X_8	Y_8	Z_8		5

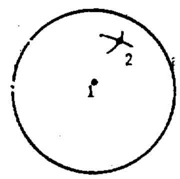
Left-adjusted, decimal format



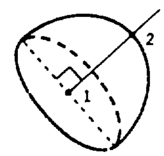
Cylinder, Type 2 (void), Type 3 (solid)



Sphere, Type 4 (void), Type 5 (solid)



Hemisphere, Type 6 (void), Type 7 (solid)

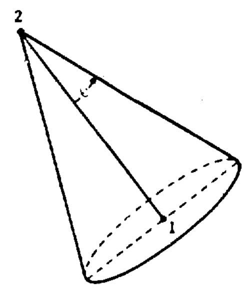


Cone, Type 8 (Void), Type 9 (Solid)

2 Points Required, Ordered as Shown

Columns	1-10	11-20	21-30	31-40	41-50	51-60	76-79	80
Card 2	X_1	Y_1	Z_1	X_2	Y_2	Z_2	Same as Card 1	2

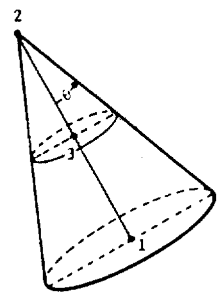
Left-adjusted, decimal format



Truncated Cone, Type 10 (Void), 11 (Solid)

3 Points Required, Ordered as Shown

Columns	1-10	11-20	21-30	31-40	41-50	51-60	76-79	80
Card 2	X_1	Y_1	Z_1	X_2	Y_2	Z_2	Same as Card 1	2
Card 3	X_3	Y_3	Z_3					3

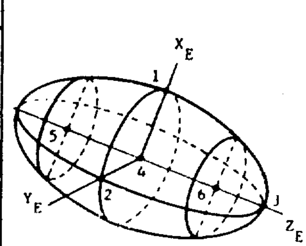


Ellipsoid, Type 12 (Void), 13 (Solid)

4, 5, or 6 Points Required (See Appendix II)

Columns	1-10	11-20	21-	31-40	41-50	51-60	76-79	80
Card 2	X_1	Y_1	Z_1	X_2	Y_2	Z_2	Same as Card 1	2
Card 3	X_3	Y_3	Z_3	X_4	Y_4	Z_4		3
Card 4 (Singly Truncated)	X_5 or X_6	Y_5 or Y_6	Z_5 or Z_6					4
Card 4 (Doubly Truncated)	X_5	Y_5	Z_5	X_6	Y_6	Z_6		4

Left-adjusted, decimal format



Best Available Copy

2. CARD LISTING

The first page of a listing of the punched card deck that describes the Computerized Anatomical Model Man follows (Figure 54). The complete card listing of all shields requires 222 pages. The combined common, standing, and seated portions of the model are contained on 13,743 cards, or 7 boxes.

371113 5		1.0600000	5	3			37111
-3.62492	0.	2.48958	0.		2.83084	2.48958	37112
0.	0.	0.	0.		0.	2.48958	37113
0.	0.	1.32000					37114
3712 0 5		0.					37121
0.	-3.50000	9.00000	0.		3.50000	9.00000	37122
0.	-3.50000	-1.00000	0.		3.50000	-1.00000	37123
5.00000	3.50000	-1.00000	5.00000		-3.50000	-1.00000	37124
5.00000	3.50000	9.00000	5.00000		-3.50000	9.00000	37125
371312 5		0.	5				37131
-2.74809	0.	1.51296	0.		2.00783	1.51296	37132
0.	0.	.35000	0.		0.	1.51296	37133
0.	0.	1.32000					37134
372113 5		1.0600000	5	3			37211
3.09515	0.	1.40075	0.		-2.50316	1.40075	37212
0.	0.	0.	0.		0.	1.40075	37213
0.	0.	1.32000					37214
3722 0 5		0.					37221
-5.00000	-3.50000	9.00000	-5.00000		3.50000	9.00000	37222
-5.00000	-3.50000	-1.00000	-5.00000		3.50000	-1.00000	37223
0.	3.50000	-1.00000	0.		-3.50000	-1.00000	37224
0.	3.50000	9.00000	0.		-3.50000	9.00000	37225
372312 5		0.	5				37231
2.71763	0.	1.62180	0.		-2.03822	1.62180	37232
0.	0.	.35000	0.		0.	1.62180	37233
0.	0.	1.32000					37234
373113 5		1.0600000	6	3			37311
-3.87931	0.	3.31468	0.		2.96534	3.31468	37312
0.	0.	-.21387	0.		0.	3.31468	37313
0.	0.	1.32000	0.		0.	2.70000	37314
3732 0 5		0.					37321
0.	-3.50000	9.00000	0.		3.50000	9.00000	37322
0.	-3.50000	-1.00000	0.		3.50000	-1.00000	37323
5.00000	3.50000	-1.00000	5.00000		-3.50000	-1.00000	37324
5.00000	3.50000	9.00000	5.00000		-3.50000	9.00000	37325
373312 5		0.	6				37331
-3.55733	0.	3.65623	0.		2.59280	3.65623	37332
0.	0.	.04984	0.		0.	3.65623	37333
0.	0.	1.32000	0.		0.	2.70000	37334
374113 5		1.0600000	6	3			37411
6.31270	0.	16.22460	0.		-4.77541	16.22460	37412
0.	0.	-.86765	0.		0.	16.22460	37413
0.	0.	1.32000	0.		0.	2.70000	37414
3742 0 5		0.					37421
-5.00000	-3.50000	9.00000	-5.00000		3.50000	9.00000	37422
-5.00000	-3.50000	-1.00000	-5.00000		3.50000	-1.00000	37423
0.	3.50000	-1.00000	0.		-3.50000	-1.00000	37424
0.	3.50000	9.00000	0.		-3.50000	9.00000	37425
374312 5		0.	6				37431
3.85004	0.	4.99025	0.		-2.80615	4.99025	37432
0.	0.	-.05216	0.		0.	4.99025	37433
0.	0.	1.32000	0.		0.	2.70000	37434

Figure 54 Portion of Card Deck Listing

APPENDIX III

LISTING OF SAMPLE PROBLEM RESULTS

1. DESCRIPTION OF PROBLEM

The demonstration of the model at the Air Force Weapons Laboratory entailed the solution of six sample problems. The results of problem number 1 are presented in this appendix. The conditions of this problem were as follows:

Dose Point - Heart

X = 1.71 in.

Y = 0.14

Z = 17.60

Model configuration - Seated

Input source - Magnetic tape

Number of rays - 512

Time required for execution - 420.813 sec

2. PROBLEM LISTING

Since the complete printout of the sample problem required 305 pages, only typical pages are reproduced in this document.

The first pages of the problem printout are a listing of the geometrical data. These data are in 2 groups. In the usual MEVDP problem, the first group describes the spacecraft. In the case of the sample problem, this group is a listing of the computerized anatomical model man. Figures 55a and 55b are the first and last pages of this listing, respectively. It is noted that except for the headings, this listing repeats the card deck listing, shown earlier as Figure 54. The complete listing used 162 pages to reproduce the information contained on the 9920 cards that depict the seated configuration. The second group of geometrical data is usually a listing of a less complex model of an astronaut that is contained in MEVDP. As shown by Figure 55c, this feature of the program was not needed for the sample calculation.

The first step of the problem execution entails checking the geometrical data and sorting the shields into octants relative to a coordinate system originating at the dose point. The result of this step is shown by Figure 55d which gives the location of the dose point; the total number of shields in the spacecraft, e.g., the computerized anatomical model man; the allocation of shields to octants; and the time required to accomplish transformation of the geometrical data from the main coordinate system to the detector coordinate system. Note that any shield intersecting one of the three principal planes of the detector coordinate system is assigned to octant 9.

The next pages of the printout show the orientation of rays originating at the detector location within a region of space also centered at the detector. Each ray is located by a pair of angles, THETA and PHI, relative to the detector coordinate system. The ranges of THETA and PHI used for the sample problem include all of the space surrounding the detector. However, the region of space may be restricted if desired. The printout includes the identification numbers of the 512 rays used; the angles THETA and PHI; and the direction cosines of the ray -- ALPHA, BETA, and GAMMA -- referred to the X, Y, and Z axes, respectively, of the detector coordinate system. This printout runs for 8½ pages. The first page is shown on Figure 55e, and the last page on Figure 55f.

The problem execution then proceeds to creation of the areal density function. This function describes the distribution of all materials and geometrical volumes comprising the shielding configuration in the equivalent total weight per unit area of a standard material (aluminum) intercepted by each ray. For heavy charged particles, it is assumed that the range-energy relationship is expressed in each material, including the standard, by the expression,

$$R = \delta E^{\eta}$$

The values of DELTA, δ, and ETA, η, used for solution of the sample problem are tabulated in the middle region of Figure 55f. It is noted that appropriate names were used, but that the range-energy coefficients are for aluminum in all cases. The time required to execute this part of the problem follows on the printout which concludes with the areal density computed for each ray. This printout begins on Figure 55f and ends on Figure 55g.

The next phase of the problem execution entails least-squares empirical fitting of the areal density distribution data. The results of this analysis begin on Figure 55g and end on Figure 55i. The maximum areal density to be included in this part of the analysis is designated XMAX -- 10.0 gm/cm^2. All 97 values of the areal density less than or equal to XMAX are then listed in ascending order of thickness. The curve has been fit in 3 sections. The printouts at the bottom of Figure 55g and the top of Figure 55h show part of the analysis of the first section. The analyses of the second and third sections are shown on Figures 55h and 55i.

The next pages of the problem printout beginning on Figure 55j and ending on Figure 55k, show the output of the subroutine ORDER of MEVDP. Each of the 56 pages of this section shows the ray number, the identity of each of several path numbers associated with the ray, the distance from the origin at the detector to the outermost point of the path, the contribution of the particular path to the total areal density along the ray, and the material along the path.

The final pages of the sample problem show the preceding data reordered by ray in ascending order, and the paths ordered from outermost to that closest to the detector. The only external organs are the eyes. The remainder of the exterior of the model man is muscle tissue. Accordingly the first path for the vast majority of the rays is always muscle. Since the detector has been located within an organ (the heart) for the sample problem, the last path is always through organ material. The intervening paths along any ray depend on the ray's orientation, and include varying numbers of paths through muscle, skeleton, and organ tissues. The execution of the sample problem requires 73 pages.

RECORD NO.	CONTENTS					
1	371113 5		1.0600000	5 3		
2	-3.62492	0.	2.48958	0.	2.83084	2.48958
3	0.	0.	0.	0.	0.	2.48958
4	0.	0.	1.32000			
5	3712 0 5		0.			
6	0.	-3.50000	9.00000	0.	3.50000	9.00000
7	0.	-3.50000	-1.00000	0.	3.50000	-1.00000
8	5.00000	3.50000	-1.00000	5.00000	-3.50000	-1.00000
9	5.00000	3.50000	9.00000	5.00000	-3.50000	9.00000
10	371312 5		0.	5		
11	-2.74809	0.	1.51296	0.	2.00783	1.51296
12	0.	0.	.35000	0.	0.	1.51296
13	0.	0.	1.32000			
14	372113 5		1.0600000	5 3		
15	3.09515	0.	1.40075	0.	-2.50316	1.40075
16	0.	0.	0.	0.	0.	1.40075
17	0.	0.	1.32000			
18	3722 0 5		0.			
19	-5.00000	-3.50000	9.00000	-5.00000	3.50000	9.00000
20	-5.00000	-3.50000	-1.00000	-5.00000	3.50000	-1.00000
21	0.	3.50000	-1.00000	0.	-3.50000	-1.00000
22	0.	3.50000	9.00000	0.	-3.50000	9.00000
23	372312 5		0.	5		
24	2.71763	0.	1.62180	0.	-2.03822	1.62180
25	0.	0.	.35000	0.	0.	1.62180
26	0.	0.	1.32000			
27	373113 5		1.0600000	6 3		
28	-3.87931	0.	3.31468	0.	2.96534	3.31468
29	0.	0.	-.21387	0.	0.	3.31468
30	0.	0.	1.32000	0.	0.	2.70000
31	3732 0 5		0.			
32	0.	-3.50000	9.00000	0.	3.50000	9.00000
33	0.	-3.50000	-1.00000	0.	3.50000	-1.00000
34	5.00000	3.50000	-1.00000	5.00000	-3.50000	-1.00000
35	5.00000	3.50000	9.00000	5.00000	-3.50000	9.00000
36	373312 5		0.	6		
37	-3.55733	0.	3.65623	0.	2.59280	3.65623
38	0.	0.	.04984	0.	0.	3.65623
39	0.	0.	1.32000	0.	0.	2.70000
40	374113 5		1.0600000	6 3		
41	6.31270	0.	16.22460	0.	-4.77541	16.22460
42	0.	0.	-.86765	0.	0.	16.22460
43	0.	0.	1.32000	0.	0.	2.70000
44	3742 0 5		0.			
45	-5.00000	-3.50000	9.00000	-5.00000	3.50000	9.00000
46	-5.00000	-3.50000	-1.00000	-5.00000	3.50000	-1.00000
47	0.	3.50000	-1.00000	0.	-3.50000	-1.00000
48	0.	3.50000	9.00000	0.	-3.50000	9.00000
49	374312 5		0.	6		
50	3.85004	0.	4.99025	0.	-2.80615	4.99025
51	0.	0.	-.05216	0.	0.	4.99025
52	0.	0.	1.32000	0.	0.	2.70000
53	375113 5		1.0600000	6 3		
54	-3.95000	0.	4.10000	0.	3.02500	4.10000
55	0.	0.	-1.40228	0.	0.	4.10000
56	0.	0.	2.70000	0.	0.	4.10000

a. Listing of Computerized Anatomical Model Man

Figure 55 Listing of Sample Problem

9915	14.33000	-3.59000	54.67220	14.28000	-3.58000	54.68870
9916	9770 1 8		1.5070000	1		
9917	14.68000	-2.73000	53.11000	14.88000	-2.53000	52.40000
9918	15.28000	-2.67540	52.05000	14.53000	-2.56180	52.05000
9919	16.53000	-3.88000	52.05000	15.28000	-3.88000	52.05000
9920	16.88000	-3.88000	52.40000	14.68000	-3.88000	53.11000

b. Listing of Computerized Anatomical Model Man (concl)

Figure 55 (cont)

SIMULATED ASTRONAUT GEOMETRY

RECORD NO.   CONTENTS

1   NO ASTRONAUTS THIS RUN

c. Listing of Astronaut Geometry

Figure 55 (cont)

```
DETECTOR POINT COORDINATES

                            Y                  Z
1.71000000E+00      1.40000000E-01     1.76000000E+01

NO. VOLUMES OF SPACECRAFT =  2271    NO. DESCRIBING ASTRONAUTS =      0

NO. SHIELDS IN OCTANT
     58          1
     50          2
     53          3
     31          4
     54          5
    192          6
     42          7
    192          8
   1599          9

TRANSFORMATION TIME=    .57 MIN
```

d. Summary of Transformations to Detector Point Coordinate System

Figure 55 (cont)

MODEL MAN SITTING

MACROSCOPIC SOLID ANGLE 1
PHI 0. 3.60000000E+02 AND THETA 0. 1.80000000E+02

RAY DIRECTION COSINES
SYSTEMATIC SELECTION FROM CENTER OF EQUAL SOLID ANGLES

	THETA (DEG)	PHI (DEG)	COS (ALPHA)	COS (BETA)	COS (GAMMA)
1	1.44775148E+01	5.62500000E+00	2.48796222E-01	2.45042887E-02	9.68245826E-01
2	1.44775148E+01	1.68750000E+01	2.39235123E-01	7.25711800E-02	9.68245826E-01
3	1.44775148E+01	2.81250000E+01	2.20480353E-01	1.17849202E-01	9.68245826E-01
4	1.44775148E+01	3.93750000E+01	1.93252647E-01	1.58598345E-01	9.68245826E-01
5	1.44775148E+01	5.06250000E+01	1.58598350E-01	1.93252642E-01	9.68245826E-01
6	1.44775148E+01	6.18750000E+01	1.17849208E-01	2.20480350E-01	9.68245826E-01
7	1.44775148E+01	7.31250000E+01	7.25711864E-02	2.39235121E-01	9.68245826E-01
8	1.44775148E+01	8.43750000E+01	2.45042953E-02	2.48796222E-01	9.68245826E-01
9	1.44775148E+01	9.56250000E+01	-2.45042820E-02	2.48796223E-01	9.68245826E-01
10	1.44775148E+01	1.06875000E+02	-7.25711735E-02	2.39235125E-01	9.68245826E-01
11	1.44775148E+01	1.18125000E+02	-1.17849196E-01	2.20480356E-01	9.68245826E-01
12	1.44775148E+01	1.29375000E+02	-1.58598339E-01	1.93252651E-01	9.68245826E-01
13	1.44775148E+01	1.40625000E+02	-1.93252638E-01	1.58598355E-01	9.68245826E-01
14	1.44775148E+01	1.51875000E+02	-2.20480347E-01	1.17849213E-01	9.68245826E-01
15	1.44775148E+01	1.63125000E+02	-2.39235119E-01	7.25711928E-02	9.68245826E-01
16	1.44775148E+01	1.74375000E+02	-2.48796221E-01	2.45043020E-02	9.68245826E-01
17	1.44775148E+01	1.85625000E+02	-2.48796224E-01	-2.45042753E-02	9.68245826E-01
18	1.44775148E+01	1.96875000E+02	-2.39235127E-01	-7.25711671E-02	9.68245826E-01
19	1.44775149E+01	2.08125000E+02	-2.20480350E-01	-1.17849190E-01	9.68245826E-01
20	1.44775148E+01	2.19375000E+02	-1.93252655E-01	-1.58598334E-01	9.68245826E-01
21	1.44775148E+01	2.30625000E+02	-1.58598360E-01	-1.93252634E-01	9.68245826E-01
22	1.44775148E+01	2.41875000E+02	-1.17849210E-01	-2.20480344E-01	9.68245826E-01
23	1.44775148E+01	2.53125000E+02	-7.25711992E-02	-2.39235118E-01	9.68245826E-01
24	1.44775148E+01	2.64375000E+02	-2.45043087E-02	-2.48796220E-01	9.68245826E-01
25	1.44775148E+01	2.75625000E+02	2.45042697E-02	-2.48796224E-01	9.68245826E-01
26	1.44775148E+01	2.86875000E+02	7.25711607E-02	-2.39235129E-01	9.68245826E-01
27	1.44775148E+01	2.98125000E+02	1.17849184E-01	-2.20480363E-01	9.68245826E-01
28	1.44775148E+01	3.09375000E+02	1.58598329E-01	-1.93252659E-01	9.68245826E-01
29	1.44775148E+01	3.20625000E+02	1.93252630E-01	-1.58598365E-01	9.68245826E-01
30	1.44775148E+01	3.31875000E+02	2.20480340E-01	-1.17849225E-01	9.68245826E-01
31	1.44775148E+01	3.43125000E+02	2.39235114E-01	-7.25712056E-02	9.68245826E-01
32	1.44775148E+01	3.54375000E+02	2.48796220E-01	-2.45043153E-02	9.68245826E-01
33	3.51823238E+01	5.62500000E+00	5.73405720E-01	5.64755331E-02	8.17322699E-01
34	3.51823238E+01	1.68750000E+01	5.51370061E-01	1.67256276E-01	8.17322699E-01
35	3.51823238E+01	2.81250000E+01	5.08145550E-01	2.71609455E-01	8.17322699E-01
36	3.51823238E+01	3.93750000E+01	4.45393310E-01	3.65524835E-01	8.17322699E-01
37	3.51823238E+01	5.06250000E+01	3.65524847E-01	4.45393301E-01	8.17322699E-01
38	3.51823238E+01	6.18750000E+01	2.71609468E-01	5.08145552E-01	8.17322699E-01
39	3.51823238E+01	7.31250000E+01	1.67256291E-01	5.51370056E-01	8.17322699E-01
40	3.51823238E+01	8.43750000E+01	5.64755485E-02	5.73405719E-01	8.17322699E-01
41	3.51823238E+01	9.56250000E+01	-5.64755177E-02	5.73405722E-01	8.17322699E-01
42	3.51823238E+01	1.06875000E+02	-1.67256262E-01	5.51370065E-01	8.17322699E-01
43	3.51823238E+01	1.18125000E+02	-2.71609441E-01	5.08145567E-01	8.17322699E-01
44	3.51823238E+01	1.29375000E+02	-3.65524823E-01	4.45393320E-01	8.17322699E-01
45	3.51823238E+01	1.40625000E+02	-4.45393291E-01	3.65524859E-01	8.17322699E-01
46	3.51823238E+01	1.51875000E+02	-5.08145545E-01	2.71609482E-01	8.17322699E-01
47	3.51823239E+01	1.63125000E+02	-5.51370052E-01	1.67256306E-01	8.17322699E-01
48	3.51823238E+01	1.74375000E+02	-5.73405717E-01	5.64755638E-02	8.17322699E-01

Ray Orientation Data

Figure 55 (cont)

483	1.65522487E+02	2.81250000E+01	2.20480368E-01	1.17849210E-01	-9.68245822E-01
484	1.65522487E+02	3.93750000E+01	1.93252660E-01	1.58598355E-01	-9.68245822E-01
485	1.65522487E+02	5.06250000E+01	1.58598361E-01	1.93252656E-01	-9.68245822E-01
486	1.65522487E+02	6.18750000E+01	1.17849215E-01	2.20480365E-01	-9.68245822E-01
487	1.65522487E+02	7.31250000E+01	7.25711913E-02	2.39235138E-01	-9.68245822E-01
488	1.65522487E+02	8.43750000E+01	2.45042970E-02	2.48796238E-01	-9.68245822E-01
489	1.65522487E+02	9.56250000E+01	-2.45042837E-02	2.48796240E-01	-9.68245822E-01
490	1.65522487E+02	1.06875000E+02	-7.25711785E-02	2.39235141E-01	-9.68245822E-01
491	1.65522487E+02	1.18125000E+02	-1.17849204E-01	2.20480371E-01	-9.68245822E-01
492	1.65522487E+02	1.29375000E+02	-1.58598350E-01	1.93252664E-01	-9.68245822E-01
493	1.65522487E+02	1.40625000E+02	-1.93252651E-01	1.58598366E-01	-9.68245822E-01
494	1.65522487E+02	1.51875000E+02	-2.20480362E-01	1.17849221E-01	-9.68245822E-01
495	1.65522487E+02	1.63125000E+02	-2.39235136E-01	7.25711977E-02	-9.68245822E-01
496	1.65522487E+02	1.74375000E+02	-2.48796238E-01	2.45043037E-02	-9.68245822E-01
497	1.65522487E+02	1.85625000E+02	-2.48796240E-01	-2.45042770E-02	-9.68245822E-01
498	1.65522487E+02	1.96875000E+02	-2.39235143E-01	-7.25711720E-02	-9.68245822E-01
499	1.65522487E+02	2.08125000E+02	-2.20480374E-01	-1.17849198E-01	-9.68245822E-01
500	1.65522487E+02	2.19375000E+02	-1.93252668E-01	-1.58598345E-01	-9.68245822E-01
501	1.65522487E+02	2.30625000E+02	-1.58598371E-01	-1.93252647E-01	-9.68245822E-01
502	1.65522487E+02	2.41875000E+02	-1.17849227E-01	-2.20480358E-01	-9.68245822E-01
503	1.65522487E+02	2.53125000E+02	-7.25712041E-02	-2.39235134E-01	-9.68245822E-01
504	1.65522487E+02	2.64375000E+02	-2.45043103E-02	-2.48796237E-01	-9.68245822E-01
505	1.65522487E+02	2.75625000E+02	2.45042703E-02	-2.48796241E-01	-9.68245822E-01
506	1.65522487E+02	2.86875000E+02	7.25711656E-02	-2.39235145E-01	-9.68245822E-01
507	1.65522487E+02	2.98125000E+02	1.17849192E-01	-2.20480377E-01	-9.68245822E-01
508	1.65522487E+02	3.09375000E+02	1.58598340E-01	-1.93252673E-01	-9.68245822E-01
509	1.65522487E+02	3.20625000E+02	1.93252643E-01	-1.58598376E-01	-9.68245822E-01
510	1.65522487E+02	3.31875000E+02	2.20480355E-01	-1.17849233E-01	-9.68245822E-01
511	1.65522487E+02	3.43125000E+02	2.39235132E-01	-7.25712105E-02	-9.68245822E-01
512	1.65522487E+02	3.54375000E+02	2.48796237E-01	-2.45043170E-02	-9.68245822E-01

NO. SOLID ANGLES IN ELEMENT	SUBTENDED SOLID ANGLE PER RAY
512	2.45436914E-02

DELTA STD = 3.03056000E-05	ETA STD = 1.75079000E-02	ALUMINUM
DELTA(1)= 3.03056000E-05	ETA(1)= 1.75079000E-02	ALUMINUM
DELTA(2)= 3.03056000E-05	ETA(2)= 1.75079000E-02	LUNG
DELTA(3)= 3.03056000E-05	ETA(3)= 1.75079000E-02	ORGAN
DELTA(4)= 3.03056000E-05	ETA(4)= 1.75079000E-02	INTESTINE
DELTA(5)= 3.03056000E-05	ETA(5)= 1.75079000E-02	MUSCLE
DELTA(6)= 3.03056000E-05	ETA(6)= 1.75079000E-02	BONE
DELTA(7)= 3.03056000E-05	ETA(7)= 1.75079000E-02	ALUMINUM
DELTA(8)= 3.03056000E-05	ETA(8)= 1.75079000E-02	SKELETON

TRACK TIME = 4.54 MIN

512 AREAL DENSITY FUNCTIONS (GM/SQ.CM.)

1	4.28923355E+01	4.75015642E+01	4.98693370E+01	5.29928812E+01	6.90817461E+01	6.13871895E+01
7	5.58550470E+01	5.52605168E+01	5.62755053E+01	6.01294509E+01	6.18105249E+01	6.26512805E+01
13	5.79251578E+01	5.82580969E+01	6.41689338E+01	7.06720974E+01	7.17758533E+01	6.92693622E+01
19	5.81049195E+01	5.75976724E+01	5.95140206E+01	6.00359839E+01	5.98363148E+01	5.47800374E+01
25	5.46516974E+01	5.57167594E+01	5.70788319E+01	6.95912762E+01	6.02417853E+01	5.02439335E+01
31	4.71331500E+01	4.06577650E+01	2.96200204E+01	5.09860077E+01	2.75711286E+01	1.80032197E+01
37	1.79167020E+01	1.93144091E+01	2.57078585E+01	2.88253525E+01	3.03413911E+01	2.88762937E+01

f. Ray Orientation Data (concl), Range-Energy Coefficients, and Areal Density Function

Figure 55 (cont)

415	9.59370929E+00	9.13521142E+00	1.03207468E+01	1.04313685E+01	1.06721666E+01	1.10301679E+01
421	1.17407077E+01	1.24797316E+01	1.32925556E+01	1.58182467E+01	1.76690742E+01	1.80529112E+01
427	1.76497303E+01	1.69387380E+01	1.49023274E+01	1.31868971E+01	1.23193202E+01	1.43672297E+01
433	1.73727078E+01	1.47133254E+01	1.26345060E+01	1.38074026E+01	1.59214712E+01	1.69528656E+01
439	1.79019208E+01	1.75990160E+01	1.57665417E+01	1.29072976E+01	1.22180383E+01	1.19305397E+01
445	1.11803825E+01	1.07109054E+01	1.04969534E+01	1.03425475E+01	1.12995856E+01	1.12982009E+01
451	1.12625104E+01	1.11180777E+01	1.11042893E+01	1.15439370E+01	1.28110014E+01	1.45254341E+01
457	1.66739437E+01	1.75101697E+01	1.68371992E+01	1.51648001E+01	1.48212523E+01	1.50493862E+01
463	1.55887005E+01	1.91165647E+01	1.98561742E+01	1.79614656E+01	1.42387107E+01	1.40554341E+01
469	1.38582308E+01	1.40773688E+01	1.61152938E+01	1.55023465E+01	1.41310073E+01	1.27113716E+01
475	1.15086587E+01	1.08254051E+01	1.09978149E+01	1.11282472E+01	1.12210693E+01	1.12790145E+01
481	1.13308841E+01	1.15131293E+01	1.20437565E+01	1.27216770E+01	1.36204214E+01	1.47260645E+01
487	1.58797915E+01	1.70154354E+01	2.02466870E+01	2.18223465E+01	2.79961655E+01	4.01962241E+01
493	4.31274344E+01	4.82179825E+01	4.70807424E+01	6.03971417E+01	6.01723920E+01	5.74411109E+01
499	4.69132309E+01	4.57763317E+01	4.04471819E+01	3.88078735E+01	2.59042205E+01	1.96051566E+01
505	1.81169381E+01	1.41792264E+01	1.40350100E+01	1.30819545E+01	1.23246060E+01	1.17733645E+01
511	1.14265172E+01	1.21942091E+01				

XMAX = 1.0000000E+01 TAU = 8.0000000E+00 DELR = 1.0500000E-02

97 WEIGHTED VALUES OF THICKNESS

8.80813762E+00	8.80813766E+00	8.80813772E+00	8.80813820E+00	8.80813959E+00
8.80814261E+00	8.80814824E+00	8.80815766E+00	8.80817227E+00	8.80819372E+00
8.80822385E+00	8.80826474E+00	8.80831849E+00	8.80838823E+00	8.80847610E+00
8.80858528E+00	8.80871895E+00	8.80888054E+00	8.80907368E+00	8.80930224E+00
8.80957029E+00	8.80988216E+00	8.81024237E+00	8.81065567E+00	8.81112705E+00
8.81166171E+00	8.81226507E+00	8.81294278E+00	8.81370072E+00	8.81454497E+00
8.81548186E+00	8.81651793E+00	8.81765995E+00	8.81891493E+00	8.82029007E+00
8.82179282E+00	8.82343087E+00	8.82521211E+00	8.82714468E+00	8.82923695E+00
8.83149752E+00	8.83393523E+00	8.83655916E+00	8.83937863E+00	8.84240323E+00
8.84564277E+00	8.84910735E+00	8.85280733E+00	8.85675334E+00	8.86095631E+00
8.86542746E+00	8.87017834E+00	8.87522089E+00	8.88056708E+00	8.88622977E+00
8.89222184E+00	8.89855673E+00	8.90524831E+00	8.91231097E+00	8.91975961E+00
8.92760978E+00	8.93587766E+00	8.94458016E+00	8.95373501E+00	8.96336084E+00
8.97347729E+00	8.98410514E+00	8.99526644E+00	9.00698479E+00	9.01928532E+00
9.03219513E+00	9.00574352E+00	9.05996227E+00	9.07488613E+00	9.09055322E+00
9.10700571E+00	9.12429046E+00	9.14245908E+00	9.16157354E+00	9.18169856E+00
9.20291245E+00	9.22530497E+00	9.24898132E+00	9.27406636E+00	9.30071036E+00
9.32909710E+00	9.35945567E+00	9.39207814E+00	9.42734721E+00	9.46578187E+00
9.50811761E+00	9.55546033E+00	9.60961843E+00	9.67395916E+00	9.75640581E+00
9.89270199E+00	1.00000000E+01			

CURVE FIT OF SECTION 1

THICKNESS	DISTRIBUTION	CURVE FIT PT.
8.80813762E+00	1.95312500E-03	1.70739549E-03
8.80813766E+00	1.95312500E-03	1.70739756E-03
8.80813772E+00	1.95312500E-03	1.70740011E-03
8.80813820E+00	1.95312500E-03	1.70742218E-03
8.80813959E+00	1.95312500E-03	1.70748533E-03
8.80814261E+00	1.95312500E-03	1.70762348E-03
8.80814824E+00	1.95312500E-03	1.70788054E-03
8.80815766E+00	1.95312500E-03	1.70831064E-03
8.80817227E+00	1.95312500E-03	1.70897812E-03

v. Areal Density Function (concl) and Least Squares Analysis

Figure 55 (cont)

9.04574352E+00	1.17187500E-02	1.25587717E-02
9.05996227E+00	1.36718750E-02	1.32081373E-02
9.07488613E+00	1.36718750E-02	1.38897044E-02
9.09055322E+00	1.36718750E-02	1.46052151E-02
9.10700571E+00	1.36718750E-02	1.53565942E-02
9.12429046E+00	1.56250000E-02	1.61459826E-02
9.14245998E+00	1.75781250E-02	1.69757783E-02
9.16157354E+00	1.75781250E-02	1.78486876E-02
9.18169856E+00	2.14843750E-02	1.87677900E-02
9.18874207E+00	2.21328584E-02	1.90894646E-02

2 COEFFICIENTS

-4.00557097E-01 4.56696420E-02

CURVE FIT OF SECTION 2

THICKNESS	DISTRIBUTION	CURVE FIT PT.
9.18874207E+00	2.21328584E-02	1.95434392E-02
9.20291245E+00	2.34375000E-02	2.06690913E-02
9.22530497E+00	2.34375000E-02	2.24478849E-02
9.24898132E+00	2.53906250E-02	2.43286624E-02
9.27406636E+00	2.53906250E-02	2.63213422E-02
9.30071036E+00	2.53906250E-02	2.84378608E-02
9.32909710E+00	2.73437500E-02	3.06928178E-02
9.35945567E+00	2.92968750E-02	3.31044110E-02
9.39207814E+00	3.51562500E-02	3.56958408E-02
9.42734721E+00	3.90625000E-02	3.84975090E-02
9.46578187E+00	4.10156250E-02	4.15506418E-02
9.50811761E+00	4.68750000E-02	4.49136653E-02
9.55546033E+00	4.88281250E-02	4.86744274E-02
9.58579265E+00	5.32036707E-02	5.10839351E-02

2 COEFFICIENTS

-7.10382412E-01 7.94369725E-02

CURVE FIT OF SECTION 3

THICKNESS	DISTRIBUTION	CURVE FIT PT.
9.58579265E+00	5.32036707E-02	5.40470543E-02
9.60961843E+00	5.66406250E-02	5.55866365E-02
9.67395918E+00	6.05468750E-02	5.97442281E-02
9.75640581E+00	6.44531250E-02	6.50717909E-02
9.89270199E+00	7.22656250E-02	7.38790215E-02
1.00000000E+01	8.20312500E-02	8.08124395E-02

2 COEFFICIENTS

h. Least Squares Analysis (cont)

Figure 55 (cont)

```
-5.65370807E-01      6.46183247E-02

GEOMDS TIME =    .01 MIN

EXECUTION TIME FOR ESDOSE IS  4.57 MIN
```

i. Least Squares Analysis (concl)

Figure 55 (cont)

NO. PATHS IS 3455 OF TOTAL 3455

RAY NO.	PATH NO.	DISTANCE TO (CM.)	PATH THROUGH (GM./SQ.CM.)	MATERIAL NO.
495	1	4.34023617E+01	7.36637773E-01	5
496	1	4.40000322E+01	9.49056606E-01	5
497	1	4.41202094E+01	8.59953277E-01	5
498	1	4.37830898E+01	1.14020841E+00	5
499	1	4.29729635E+01	2.81475675E-01	5
493	1	4.01456456E+01	1.12189053E+00	5
494	1	4.21049712E+01	1.97819089E+00	5
495	2	4.27074204E+01	7.11862975E-01	5
498	2	4.27074204E+01	9.32872077E-02	5
499	2	4.27074204E+01	1.46565028E+00	5
500	1	4.14181335E+01	2.32281107E+00	5
501	1	3.93058113E+01	2.31666263E-01	5
492	1	3.71503464E+01	1.93985936E+00	5
493	2	3.90872593E+01	1.56783082E+00	5
501	2	3.90872593E+01	2.86603518E+00	5
502	1	3.64841138E+01	7.16547226E-01	5
492	2	3.54146300E+01	4.17105642E+00	5
493	3	3.27596649E+01	1.35670348E+00	5
494	2	3.19350197E+01	3.76669505E-01	5
500	2	3.21354976E+01	6.95176070E-01	5
501	3	3.33455380E+01	1.97781893E+00	5
502	2	3.58081259E+01	2.71073002E+00	5
502	3	3.32508334E+01	2.43357290E+00	5
512	1	3.13719238E+01	8.40266393E-01	5
512	2	3.04958289E+01	7.82989332E-02	5
492	3	3.14796711E+01	4.33906324E+00	5
493	4	3.14796711E+01	4.36570572E+00	5
494	3	3.14796711E+01	4.36570572E+00	5
495	3	3.09618862E+01	3.81685379E+00	5
496	2	3.06785028E+01	3.51646732E+00	5
497	2	3.07174059E+01	3.19306216E+00	5
498	3	3.07739186E+01	3.61760806E+00	5
499	3	3.13428688E+01	4.22069524E+00	5
500	3	3.14796711E+01	4.36570572E+00	5
501	4	3.14796711E+01	4.33906703E+00	5
502	4	3.09550099E+01	6.51859481E-01	5
489	1	3.25189732E+01	3.27458137E-02	5
490	1	3.28917665E+01	3.03169544E-02	5
504	1	3.25189734E+01	3.27458404E-02	5
489	2	3.25189732E+01	3.27458137E-02	5
503	1	3.28917667E+01	3.03169369E-02	5
504	2	3.25189734E+01	3.27458404E-02	5
493	5	2.78070428E+01	4.72719728E-01	5
494	4	2.79070428E+01	4.72719728E-01	5
495	4	2.78070428E+01	4.72719728E-01	5
496	3	2.78070428E+01	4.72719728E-01	5
497	3	2.78070428E+01	4.72719728E-01	5
498	4	2.78070428E+01	4.72719728E-01	5
499	4	2.78070628E+01	4.72719728E-01	5
500	4	2.78070428E+01	4.72719728E-01	5
501	5	2.78070428E+01	1.85863105E-01	5
493	6	2.78070428E+01	4.72719728E-01	5
494	5	2.78070428E+01	4.72719728E-01	5
495	5	2.78070428E+01	4.72719728E-01	5
499	5	2.78070428E+01	4.72719728E-01	5
500	5	2.79070428E+01	4.72719728E-01	5

j. ORDER Printout

Figure 55 (cont)

33	7	5.32528053E+01	2.02774726E+00	5
33	8	5.43098960E+01	7.86591008E-01	5
34	9	4.73870691E+01	2.54330708E+00	5
35	6	5.40838925E+01	9.64751144E+00	5
33	9	5.43866332E+01	8.13414053E-02	5
34	10	5.89081001E+01	6.60469836E-02	5
33	10	5.95127186E+01	3.17007719E+00	5
34	11	5.95127186E+01	6.40895507E-01	5
33	11	6.64736871E+01	7.37862663E+00	5
34	12	6.31078711E+01	3.81086171E+00	5
34	13	9.74834672E+01	1.78943300E+00	5
34	14	4.95902921E+01	1.00310115E-01	5
33	12	5.35678290E+01	3.33925160E-01	5
34	15	5.20098179E+01	4.90011375E+00	5
34	16	5.89457917E+01	6.07224392E+00	5
34	17	6.61899246E+01	3.26699092E+00	5
34	18	6.87451141E+01	4.04343594E-01	5
34	19	7.09044144E+01	2.28886043E+00	5
10	17	4.48585311E+01	3.16265761E+00	8
34	20	5.20098179E+01	3.64622536E+00	8
34	21	5.31172597E+01	1.66891475E+00	8
34	22	6.83636579E+01	3.27581009E+00	8
22	16	5.24639377E+01	1.35215079E+00	5
23	17	5.22699173E+01	1.70059076E+00	5
24	17	5.22073820E+01	2.57740935E+00	5
25	14	5.23422271E+01	4.53088866E+00	5
26	13	5.26703053E+01	8.06565261E+00	5
27	12	5.27809150E+01	1.26023310E+01	5
28	13	5.27809150E+01	1.73021648E+01	5
29	11	5.27809150E+01	1.67604108E+01	5
30	6	5.27809150E+01	1.58403985E+01	5
31	7	5.26073806E+01	1.41274841E+01	5
32	7	4.99850740E+01	8.44845406E+00	5
62	7	4.95983390E+01	5.33489311E+00	5
62	8	5.51189766E+01	9.28007920E-01	5
63	8	4.74921122E+01	2.37026437E+00	5
63	9	5.90612218E+01	6.46942348E-02	5
63	10	5.95127186E+01	4.78586582E-01	5
64	9	5.95127186E+01	1.42759062E+00	5
63	11	6.30574311E+01	3.75739534E+00	5
64	10	6.41564027E+01	4.92230521E+00	5
63	12	9.74859599E+01	1.13482215E+00	5
62	9	5.42434974E+01	4.92386793E+00	5
63	13	5.21028574E+01	4.88738994E+00	5
63	14	5.90001895E+01	6.23590583E+00	5
63	15	6.83294182E+01	5.58830631E+00	5
63	16	6.87909808E+01	4.52959873E-01	5
63	17	7.19401301E+01	3.33809828E+00	5
23	18	4.48585311E+01	1.39536863E+00	8
63	18	5.31172594E+01	1.52870392E+00	8
63	19	6.83636601E+01	5.16025478E-02	8

AREAL DENSITIES, SORTED ACCORDING TO RAY NO. AND DISTANCE

RAY NO.	PATH NO.	DISTANCE TO (CM.)	PATH THROUGH (GM./SQ.CM.)	MAT. NO.	MAT. NAME
1	1	5.10132767E+01	1.08547788E+01	5	MUSCLE

k. ORDER Printout (concl) and Sorted Areal Densities

Figure 55 (cont)

Best Available Copy

	2	3.02599386E+01	3.15621051E+00	5	MUSCLE
	3	2.72823815E+01	5.56140853E+00	5	MUSCLE
	4	2.20357697E+01	2.78070427E+00	5	MUSCLE
	5	1.94124638E+01	4.48782908E-01	5	MUSCLE
	6	1.89890836E+01	1.20416233E+01	3	ORGAN
	7	7.60758715E+00	8.04882720E+00	3	ORGAN
2	1	5.27809150E+01	1.50069546E+01	5	MUSCLE
	2	3.06916240E+01	3.61379702E+00	5	MUSCLE
	3	2.72823815E+01	5.56140853E+00	5	MUSCLE
	4	2.20357697E+01	2.78070427E+00	5	MUSCLE
	5	1.94124638E+01	1.65960332E-01	5	MUSCLE
	6	1.92558974E+01	1.23239122E+01	3	ORGAN
	7	7.60758715E+00	8.04882720E+00	3	ORGAN
3	1	5.27809150E+01	1.63028718E+01	5	MUSCLE
	2	3.17031039E+01	4.68596579E+00	5	MUSCLE
	3	2.72823815E+01	5.56140853E+00	5	MUSCLE
	4	2.20357697E+01	2.78070427E+00	5	MUSCLE
	5	1.94124638E+01	1.24895594E+01	3	ORGAN
	6	7.60758715E+00	8.04882720E+00	3	ORGAN
4	1	5.27809150E+01	1.70826024E+01	5	MUSCLE
	2	3.28060444E+01	2.93674160E-01	5	MUSCLE
	3	3.28060444E+01	2.93674160E-01	5	MUSCLE
	4	3.28060444E+01	2.93674160E-01	5	MUSCLE
	5	3.28060444E+01	2.93674160E-01	5	MUSCLE
	6	3.28060444E+01	2.93674160E-01	5	MUSCLE
	7	3.25289933E+01	5.56140853E+00	5	MUSCLE
	8	2.72823815E+01	5.56140853E+00	5	MUSCLE
	9	2.20357697E+01	2.78070427E+00	5	MUSCLE
	10	1.94124638E+01	1.24895594E+01	3	ORGAN
	11	7.60758715E+00	8.04882720E+00	3	ORGAN
5	1	5.27809150E+01	1.75256057E+01	5	MUSCLE
	2	3.55883052E+01	1.94481621E+00	4	INTESTINE
	3	3.53911473E+01	3.03388324E+00	5	MUSCLE
	4	3.53911473E+01	3.03388324E+00	5	MUSCLE
	5	3.53911473E+01	3.03388324E+00	5	MUSCLE
	6	3.53911473E+01	3.03388324E+00	5	MUSCLE
	7	3.53911473E+01	3.03388324E+00	5	MUSCLE
	8	3.25289933E+01	5.56140853E+00	5	MUSCLE
	9	2.72823815E+01	5.56140853E+00	5	MUSCLE
	10	2.20357697E+01	2.78070427E+00	5	MUSCLE
	11	1.94124638E+01	1.24895594E+01	3	ORGAN
	12	7.60758715E+00	8.04882720E+00	3	ORGAN
6	1	5.27809150E+01	1.40214729E+01	5	MUSCLE
	2	3.95531103E+01	4.03220372E-01	4	INTESTINE
	3	3.73850780E+01	3.09646759E+00	4	INTESTINE
	4	3.64223142E+01	3.97419050E-01	5	MUSCLE
	5	3.60473906E+01	1.14585555E-01	5	MUSCLE
	6	3.59392910E+01	3.61491555E+00	5	MUSCLE
	7	3.59392910E+01	3.61491555E+00	5	MUSCLE
	8	3.59392910E+01	3.61491555E+00	5	MUSCLE
	9	3.59392910E+01	3.61491555E+00	5	MUSCLE
	10	3.59392910E+01	3.61491555E+00	5	MUSCLE

1. Sorted Areal Densities (cont)

Figure 55 (cont)

	8	4.98428126E+00	5.27336957E+00	3	ORGAN
507	1	1.44589556E+01	2.81180607E-01	5	MUSCLE
	2	1.41936909E+01	3.62788882E+00	5	MUSCLE
	3	1.07711543E+01	1.65316172E+00	8	SKELETON
	4	9.67417903E+00	4.23574365E-01	2	LUNG
	5	7.60796261E+00	2.77365488E+00	3	ORGAN
	6	4.98428126E+00	5.27336957E+00	3	ORGAN
508	1	1.37250028E+01	2.92128452E-01	5	MUSCLE
	2	1.34494099E+01	3.30057857E+00	5	MUSCLE
	3	1.03356566E+01	1.68292806E+00	8	SKELETON
	4	9.21891599E+00	4.67989705E-01	2	LUNG
	5	6.93603939E+00	2.06496010E+00	3	ORGAN
	6	4.98428126E+00	5.27336957E+00	3	ORGAN
509	1	1.31235546E+01	3.03949244E-01	5	MUSCLE
	2	1.28368100E+01	3.03619459E+00	5	MUSCLE
	3	9.97247553E+00	1.68943738E+00	8	SKELETON
	4	8.85141556E+00	4.97424906E-01	2	LUNG
	5	6.42495260E+00	1.52423028E+00	3	ORGAN
	6	4.98428126E+00	5.27336957E+00	3	ORGAN
510	1	1.26672228E+01	3.13146662E-01	5	MUSCLE
	2	1.23718015E+01	2.84205365E+00	5	MUSCLE
	3	9.69061877E+00	1.68438920E+00	8	SKELETON
	4	8.57290562E+00	5.13428223E-01	2	LUNG
	5	6.06838070E+00	1.14697721E+00	3	ORGAN
	6	4.98428126E+00	5.27336957E+00	3	ORGAN
511	1	1.23596979E+01	3.18328188E-01	5	MUSCLE
	2	1.20593383E+01	2.71829590E+00	5	MUSCLE
	3	9.49495819E+00	1.67654090E+00	8	SKELETON
	4	8.38245593E+00	5.17976168E-01	2	LUNG
	5	5.85574292E+00	9.22006436E-01	3	ORGAN
	6	4.98428126E+00	5.27336957E+00	3	ORGAN
512	1	3.13719238E+01	8.40266393E-01	5	MUSCLE
	2	3.08958289E+01	7.82989332E-02	5	MUSCLE
	3	1.22007493E+01	3.19089051E-01	5	MUSCLE
	4	1.18997219E+01	2.66272169E+00	5	MUSCLE
	5	9.38772027E+00	1.67158670E+00	8	SKELETON
	6	8.27850548E+00	5.12478954E-01	2	LUNG
	7	5.77860814E+00	8.40397841E-01	3	ORGAN
	8	4.98428126E+00	5.27336957E+00	3	ORGAN

m. Sorted Areal Densities (concl)

Figure 55 (concl)

REFERENCES

1. C. S. Warren, J. C. Lill, R. G. Richmond, and W. G. Davis: "Radiation Dosimetry on the Gemini and Apollo Missions." Journal of Spacecraft and Rockets, Volume 5, No. 2, February 1968, p 207-210.

2. C. A. Berry: Radiation Dose Levels for Apollo Crew Members, Apollo Applications Program. U.S. Government Memorandum, 10 February 1967.

3. W. Helvey, C. Martell, J. Peters, G. Rosenthal, F. Benjamin, and G. Albright: Biomedical and Human Factor Requirements for a Manned Earth Orbiting Station. RAC 1781A (ARD-FR-63-144A). Republic Aviation Corporation, Farmingdale, Long Island, New York, Revised 3 January 1964.

4. B. Liley and S. C. Hamilton, Modified Elemental Dose Program (EVDP). AFWL-TR-69-68. North American Rockwell Corporation, Los Angeles, California, August 1969.

5. H. T. E. Hertzberg, G. J. Daniels, and E. Churchill: Anthropometry of Flying Personnel - 1950. WADC-TR-52-321 (AD 47953), Wright Air Development Center, Dayton, Ohio, September 1954.

6. D. J. Morton: Manual of Human Cross Section Anatomy. Williams and Wilkins Company, Baltimore, Maryland, 1944.

7. A. C. Eycleshymer and D. M. Shoemaker: A Cross Section Anatomy. D. Appleton and Company, New York, New York, 1923.

8. J. C. B. Grant: An Atlas of Anatomy (Volumes I and II), Williams and Wilkins Company, Baltimore, Maryland, 1943.

9. C. Long, Editor: Biochemists' Handbook. D. Van Nostrand Company, Inc., Princeton, New Jersey, 1968.

10. W. S. Spector, Editor: Handbook of Biological Data. W. B. Saunders Company, Philadelphia, Pennsylvania, 1956.

11. F. Frohse, M. Brodel, and L. Schlossberg: Atlas of Human Anatomy. Barnes and Nobel, Inc., New York, New York, 1967.

12. K. F. Armstrong and D. J. Kidd: Atlas of Male Anatomy. Bailliere, Tindall and Cassell, London, England, 1967.

13. P. I. Altman and D. S. Dittmer, Editors: Biology Data Book. Federated American Society of Experimental Biologists, Washington, D.C. 1964.

14. O. Glasser: Medical Physics. The Year Book Publishers, Inc., 1947.

15. K. Z. Morgan, Editor: "Report of ICRP Committee II on Permissable Dose for Internal Radiation (1959)", Health Physics, Volume 3. Pergamon Press, Inc., New York, New York, June 1960.

16. M. J. Berger and S. M. Seltzer: Tables of Energy Losses and Ranges of Electrons and Positrons. NASA SP-3012, National Bureau of Standards, Washington, D.C., 1964.

17. W. F. Sunderman and F. Barner: Normal Values in Clinical Medicine. W. B. Saunders Company, Philadelphia, Pennsylvania, 1949.

18. Southall: Physiological Optics. Dover Publishing Company, New York, New York, 1961.

BIBLIOGRAPHY

Anson, B. J.: Morris' Human Anatomy; (12th Ed). McGraw Hill Book Company, New York, New York, 1966.

Appleton, A. B.: W. J. Hamilton, and G. Simon: Surface and Radiological Anatomy; Williams and Wilkins Company, Baltimore, Maryland, 1946.

Brozek, J.: Human Body Composition; Pergamon Press, Inc., Oxford, England, 1965

Churchill, E., and G. S. Daniels: Nomographs of Head Measurements. WADC-TR-53-14 (AD-16748), Wright Air Development Center, Dayton, Ohio, May 1953.

Diem, K.: Documenta Geigy - Scientific Tables; (6th Ed), Geigy Pharmaceuticals, Ardsley, New York.

Eycleshymer, A. C., and D. M. Shoemaker: A Cross-Section Anatomy; D. Appleton and Company, New York, New York, 1923.

Hanavan, E. P.: A Mathematical Model of the Human Body: AMRL-TP-64-102 (AD-608463), Aerospace Medical Research Laboratories, Dayton, Ohio, October 1964.

Hansen, R., D. Y. Cornog, and H. L. Zoh: Annotated Bibliography of Applied Physical Anthropology in Human Engineering: WADC-TR-56-30 (AD-155622), Wright Air Development Center, Dayton, Ohio, May 1958.

Hertzberg, H. T. E., G. S. Daniels and E. Churchill: Anthropometry of Flying Personnel - 1950. WADC-TR-52-321 (AD-47953), Wright Air Development Center, Dayton, Ohio, September 1954.

Leffler, J. M.: Shielded Primary Proton Spectra and Dose Formulas; Inter-Office letter, North American Rockwell Corporation, Los Angeles, Calif., 20 August 1962.

Liley, B., S. C. Hamilton, and J. D. Fletcher: Numerical Model Representing the Geometrical Shielding of the Lunar Module; SD 68-798, Space Division North American Rockwell Corporation, Los Angeles, California, Sept. 1968.

Moore, F. D., et al: The Body Cell Mass; W. B. Saunders Company, Philadelphia, Pennsylvania.

Morgan, K. Z., Editor: "Report of ICRP Committee II on Permissible Dose for Internal Radiation (1959)", Health Physics, Volume 3, Pergamon Press, Inc., New York, New York, June 1960.

Morton, D. J.: Manual of Human Cross Section Anatomy; Williams and Wilkins Company, Baltimore, Maryland, 1944.

McConville, J. T., M. Alexander, and S. M. Velsey: Anthropometric Data in Three Dimensional Form: Development and Fabrication of USAF Height - Weight - Manikins: AMRL-TDR-63-55 (AD-411556), Aerospace Medical Research Laboratories, Dayton, Ohio, June 1963.

McKenzie, S. K.: An Annotated Bibliography of USAF Physical Anthropology for the Period 1946 to 1968. (9th Ed.) Anthropology Branch, Aerospace Medical Research Laboratories, Dayton, Ohio.

Report of the International Commission on Radiobiological Units and Measurements (ICRU), NBS Handbook No. 62, National Bureau of Standards, Washington, D. C., 1956.

Roebuck, J. A.: Development of Mathematical Models and Computer Program for Workspace Design and Analysis. PTP-13100, Space Division, North American Rockwell Corporation, Los Angeles, California.

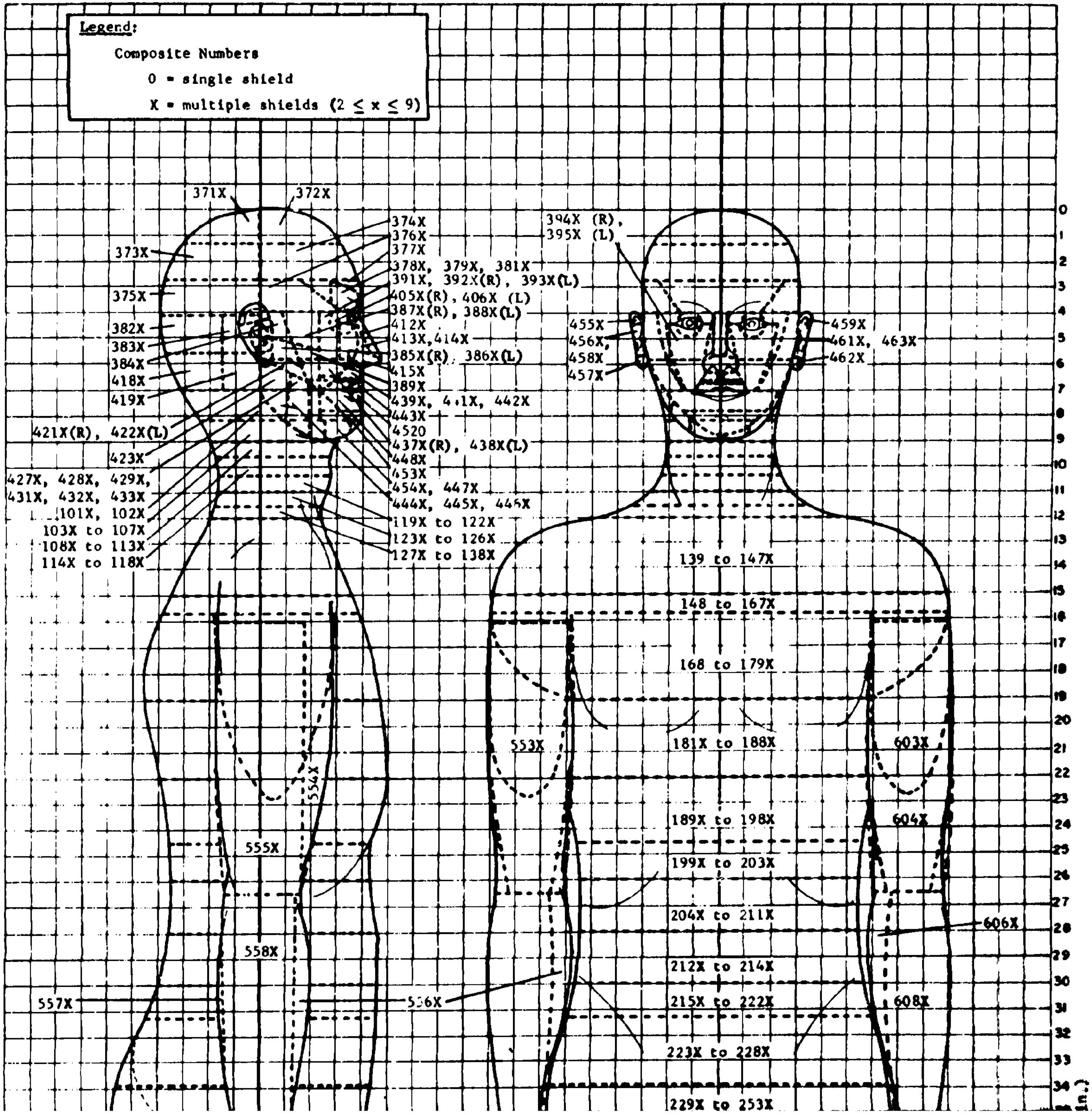
Roebuck, J. A.: Models of Musculo-Skeletal Mechanics: Engineering Course 230B, University of California, Los Angeles, California.

Steinheimer, R. M.: "Range-Energy Relations for Protons in Various Substances," Physical Review, Volume 118, Number 4, May 1960, P. 1046.

The Autopsy. Armed Forces Institute of Pathology, Washington, D. C., 1951.

Topping, P. C., and J. A. Roebuck: Computer Program for NASA Anthropometry File and Report (Program No. AFB152B), PTP-13100 Space Division, North American Rockwell Corporation, Los Angeles, California.

Truex, R. C., and C. E. Kellner: Detailed Atlas of the Head and Neck; Oxford University Press, New York, New York, 1948.


Legend:
Composite Numbers
0 = single shield
X = multiple shields (2 ≤ x ≤ 9)
371X
372X
373X
375X
382X
383X
384X
418X
419X
421X(R), 422X(L)
423X
427X, 428X, 429X,
431X, 432X, 433X
101X, 102X
103X to 107X
108X to 113X
114X to 118X
374X
376X
377X
378X, 379X, 381X
391X, 392X(R), 393X(L)
405X(R), 406X (L)
387X(R), 388X(L)
412X
413X, 414X
385X(R), 386X(L)
415X
389X
439X, 441X, 442X
443X
4520
437X(R), 438X(L)
448X
453X
454X, 447X
444X, 445X, 446X
119X to 122X
123X to 126X
127X to 138X
394X (R),
395X (L)
455X
456X
458X
457X
459X
461X, 463X
462X
139 to 147X
148 to 167X
168 to 179X
181X to 188X
189X to 198X
199X to 203X
204X to 211X
212X to 214X
215X to 222X
223X to 228X
229X to 253X
553X
554X
555X
556X
557X
558X
603X
604X
606X
608X
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
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33
34

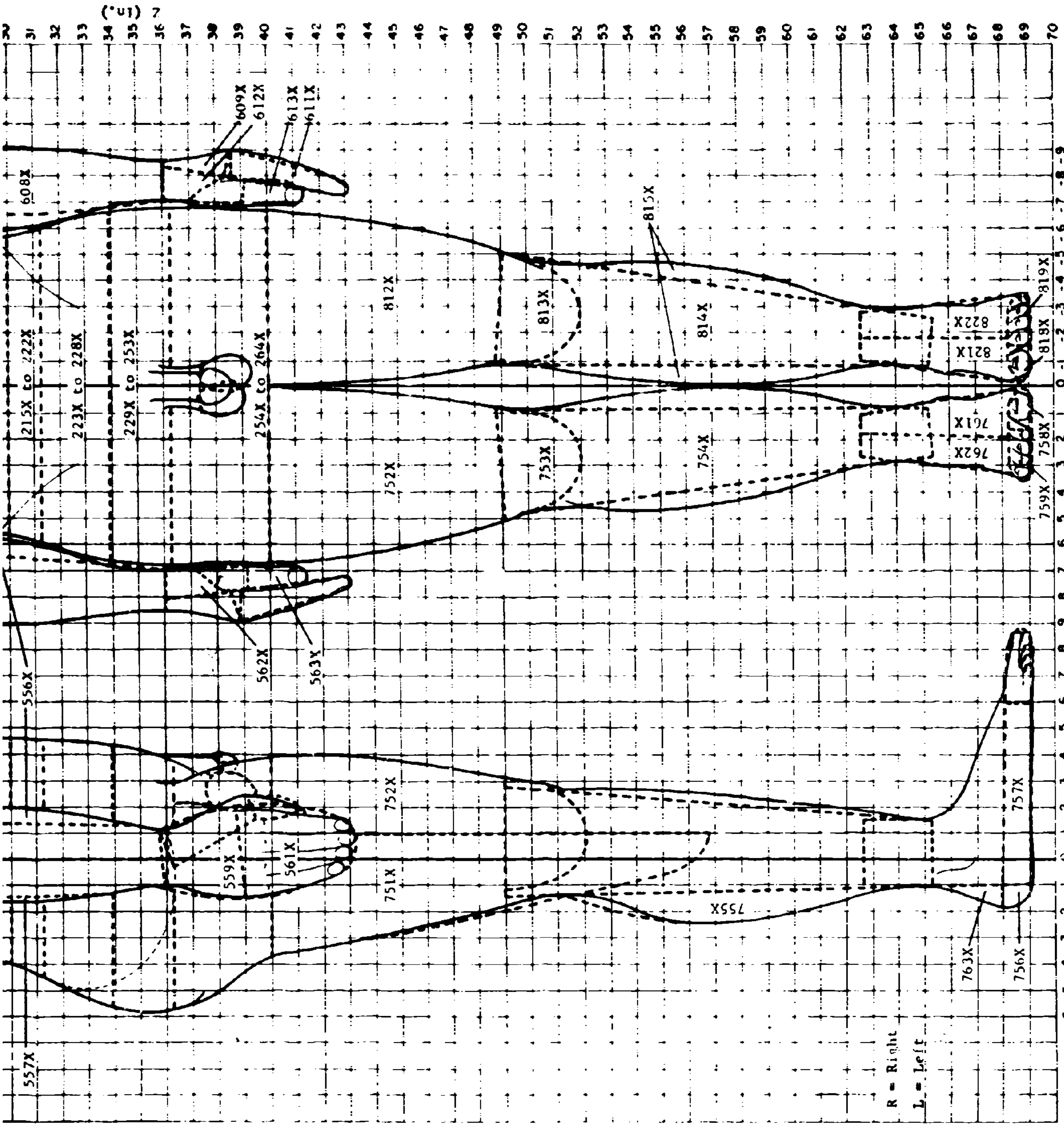
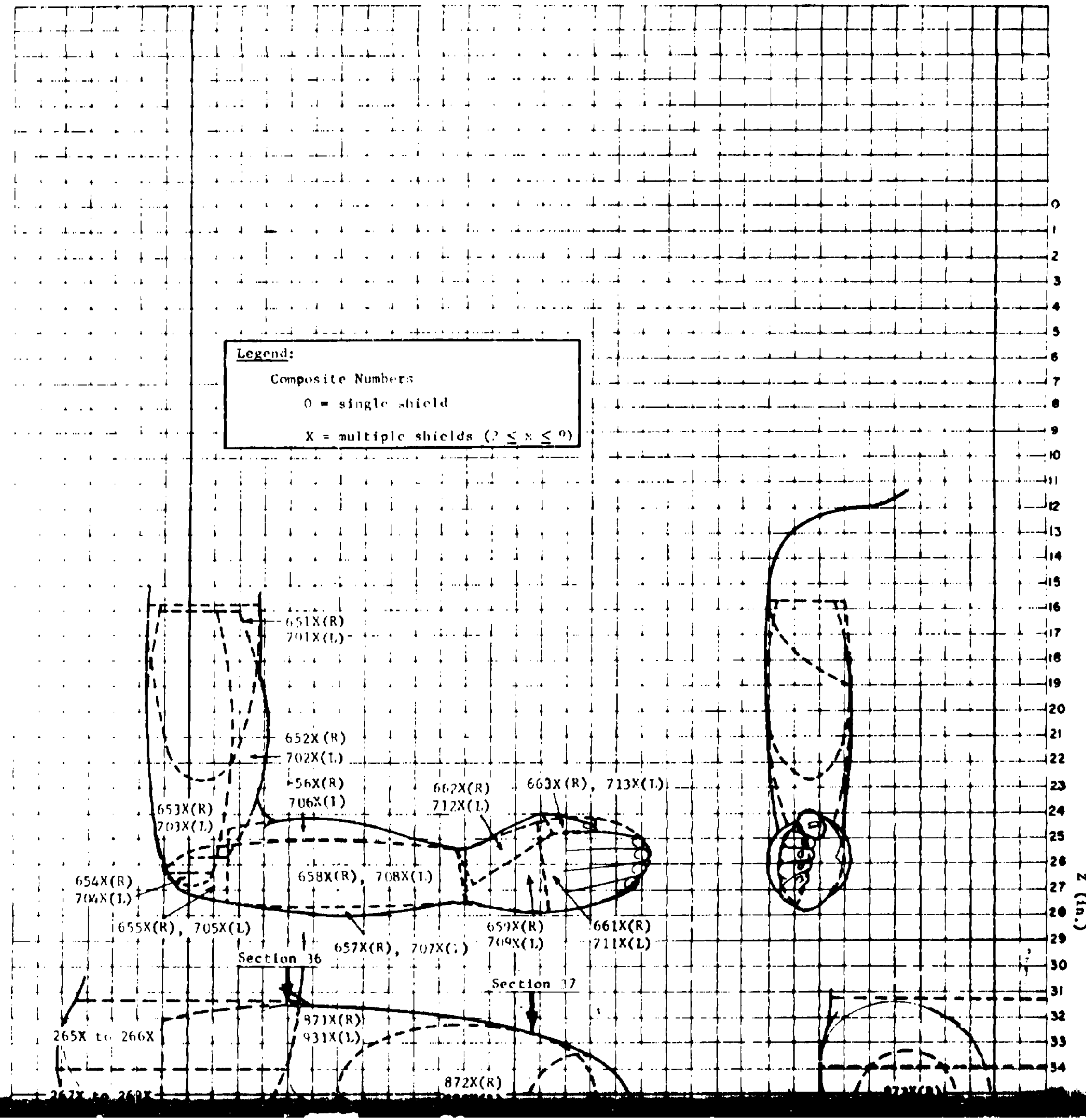


Figure 19 Composite Shields in the Muscle Portion, Standing Man

B

A



Legend:
Composite Numbers
0 = single shield
X = multiple shields (2 ≤ x ≤ 9)
Z (in.)
651X(R)
701X(L)
652X(R)
702X(L)
656X(R)
706X(L)
653X(R)
703X(L)
654X(R)
704X(L)
655X(R), 705X(L)
657X(R), 707X(L)
658X(R), 708X(L)
662X(R)
712X(L)
663X(R), 713X(L)
659X(R)
709X(L)
661X(R)
711X(L)
Section 36
Section 37
871X(R)
931X(L)
265X to 266X
872X(R)

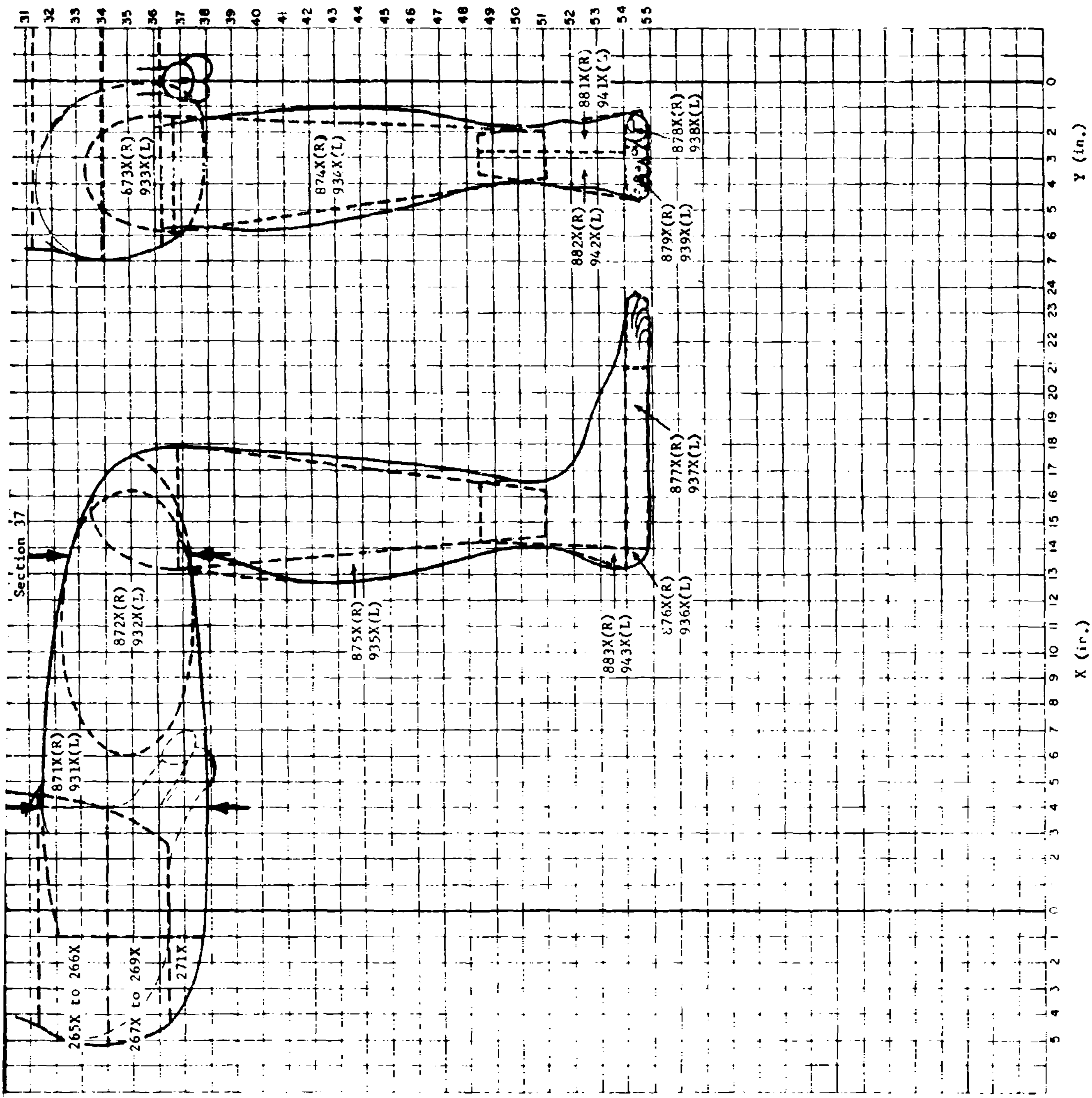
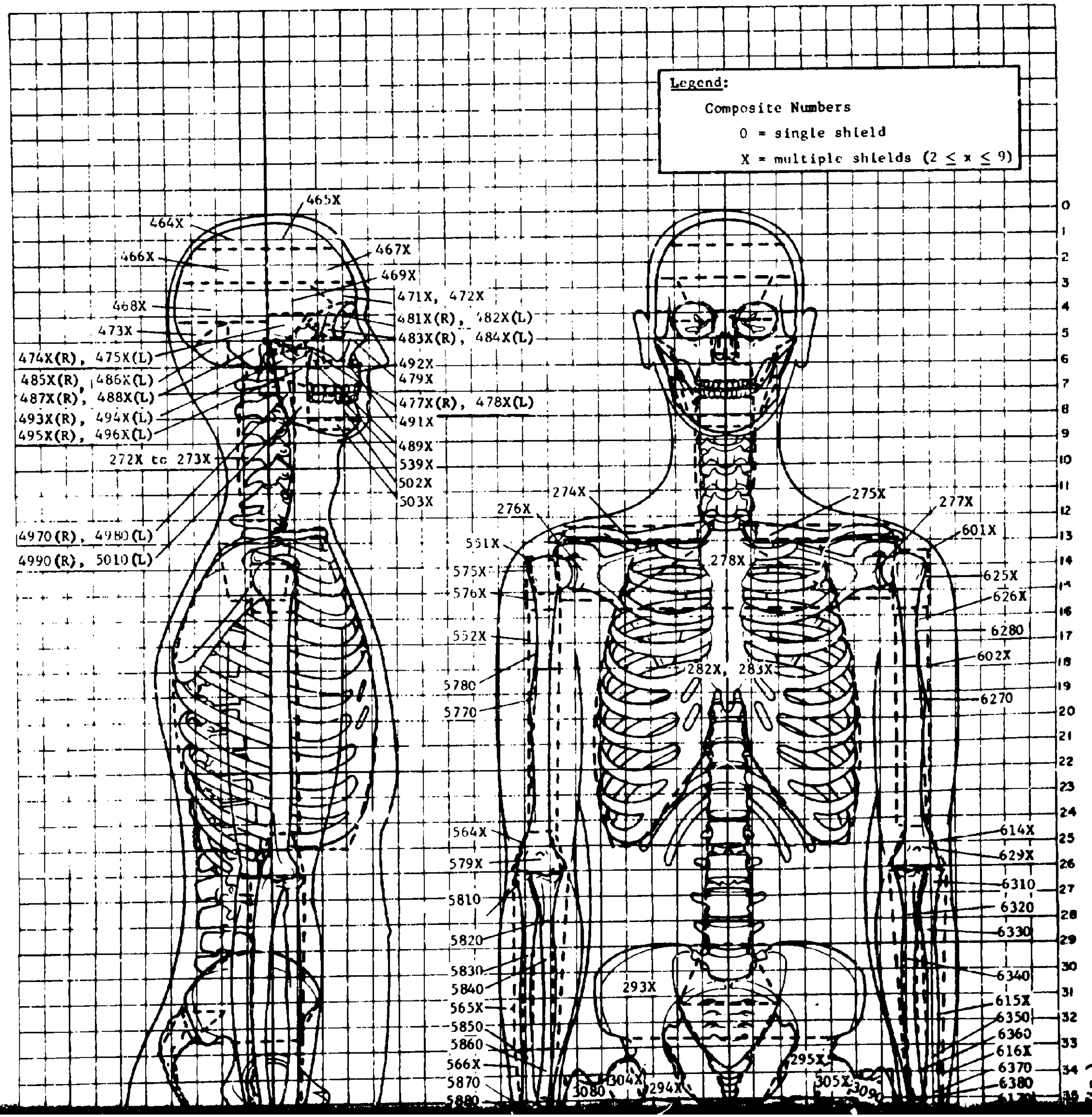


Figure 20 Composite Shields in the Muscle Portion, Seated Man

B



Legend:
Composite Numbers
0 = single shield
X = multiple shields (2 ≤ x ≤ 9)
464X
465X
466X
467X
469X
468X
471X, 472X
481X(R), 482X(L)
473X
483X(R), 484X(L)
474X(R), 475X(L)
492X
485X(R), 486X(L)
479X
487X(R), 488X(L)
477X(R), 478X(L)
493X(R), 494X(L)
491X
495X(R), 496X(L)
489X
272X to 273X
539X
502X
503X
4970(R), 4980(L)
4990(R), 5010(L)
274X
275X
276X
277X
601X
551X
278X
575X
625X
576X
626X
6280
552X
602X
282X, 283X
5780
6270
5770
564X
614X
579X
629X
6310
5810
6320
6330
5820
5830
6340
5840
293X
615X
565X
6350
5850
6360
5860
295X
616X
566X
6370
5870
304X
294X
305X
6380
3080
3090
5880
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
(in.)

A

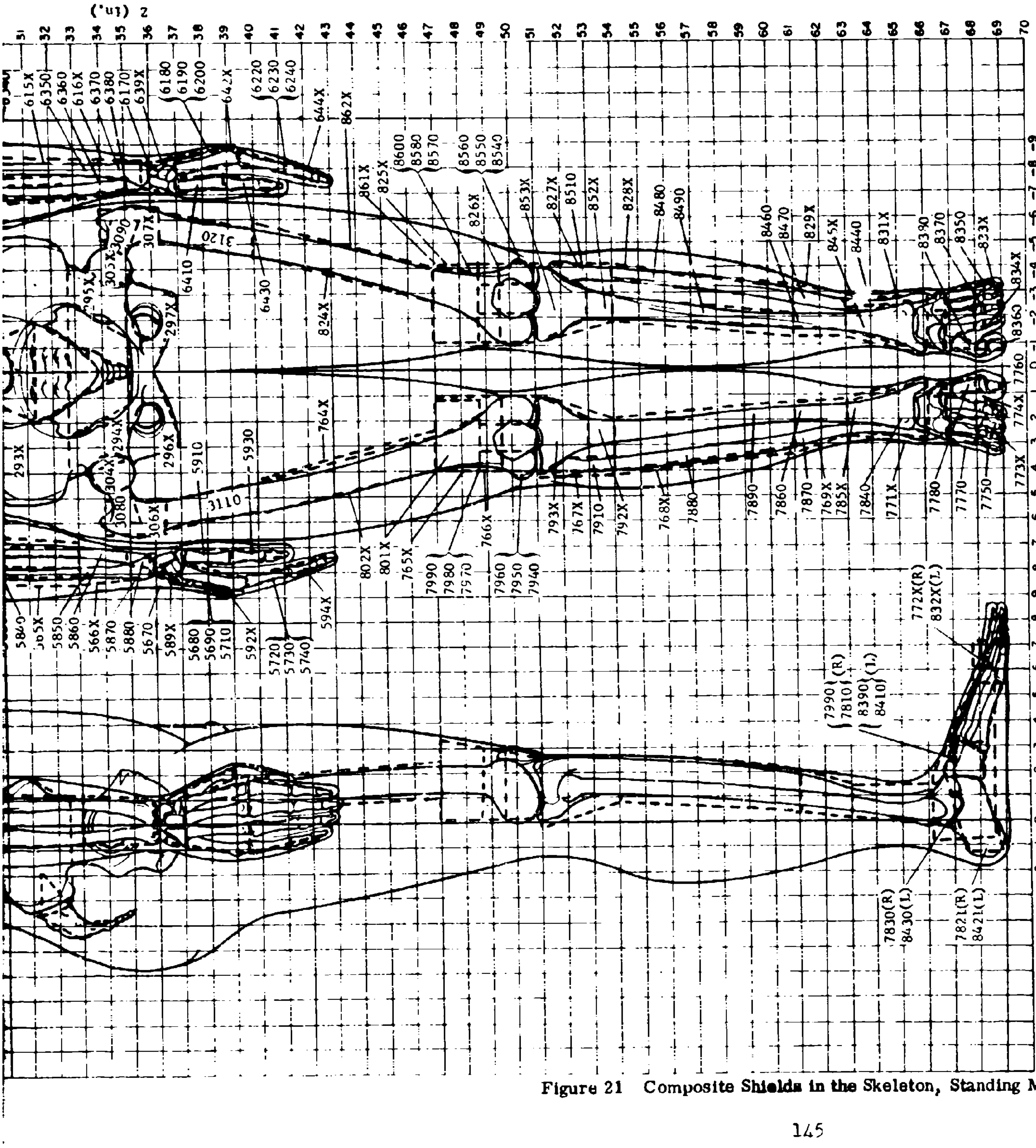
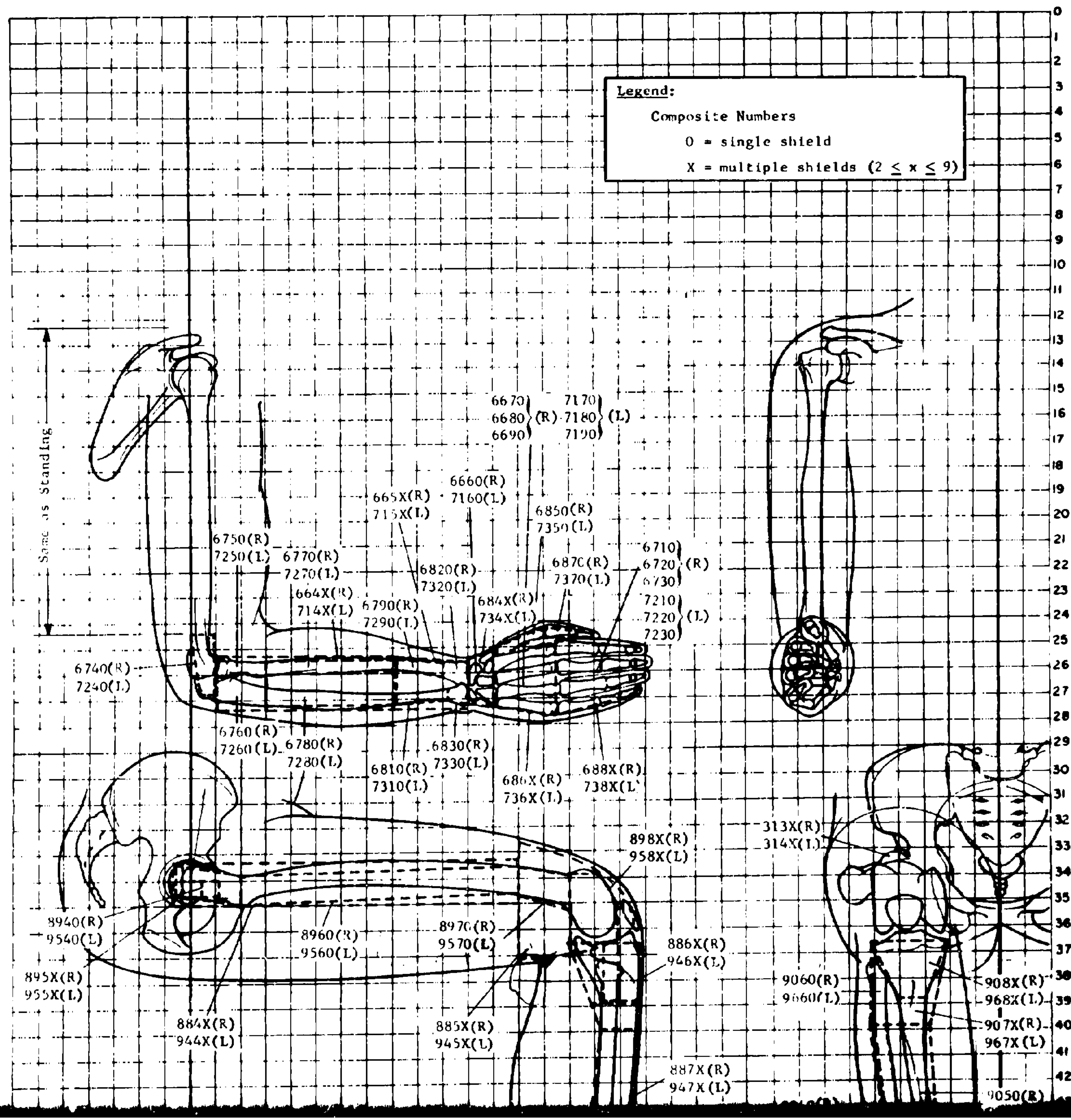


Figure 21 Composite Shields in the Skeleton, Standing Man

B



Legend:
Composite Numbers
0 = single shield
X = multiple shields (2 ≤ x ≤ 9)
z (in.)
Same as Standing
6670 6680 6690 (R) 7170 7180 7190 (L)
6660(R) 7160(L)
665X(R) 715X(L)
6850(R) 7350(L)
6710 6720 6730 (R)
7210 7220 7230 (L)
6870(R) 7370(L)
6750(R) 7250(L)
6770(R) 7270(L)
6820(R) 7320(L)
664X(R) 714X(L)
6790(R) 7290(L)
684X(R) 734X(L)
6740(R) 7240(L)
6760(R) 7260(L)
6780(R) 7280(L)
6810(R) 7310(L)
6830(R) 7330(L)
686X(R) 736X(L)
688X(R) 738X(L)
313X(R) 314X(L)
898X(R) 958X(L)
8940(R) 9540(L)
8960(R) 9560(L)
8970(R) 9570(L)
886X(R) 946X(L)
895X(R) 955X(L)
884X(R) 944X(L)
885X(R) 945X(L)
887X(R) 947X(L)
9060(R) 9660(L)
908X(R) 968X(L)
907X(R) 967X(L)
9050(R)

A

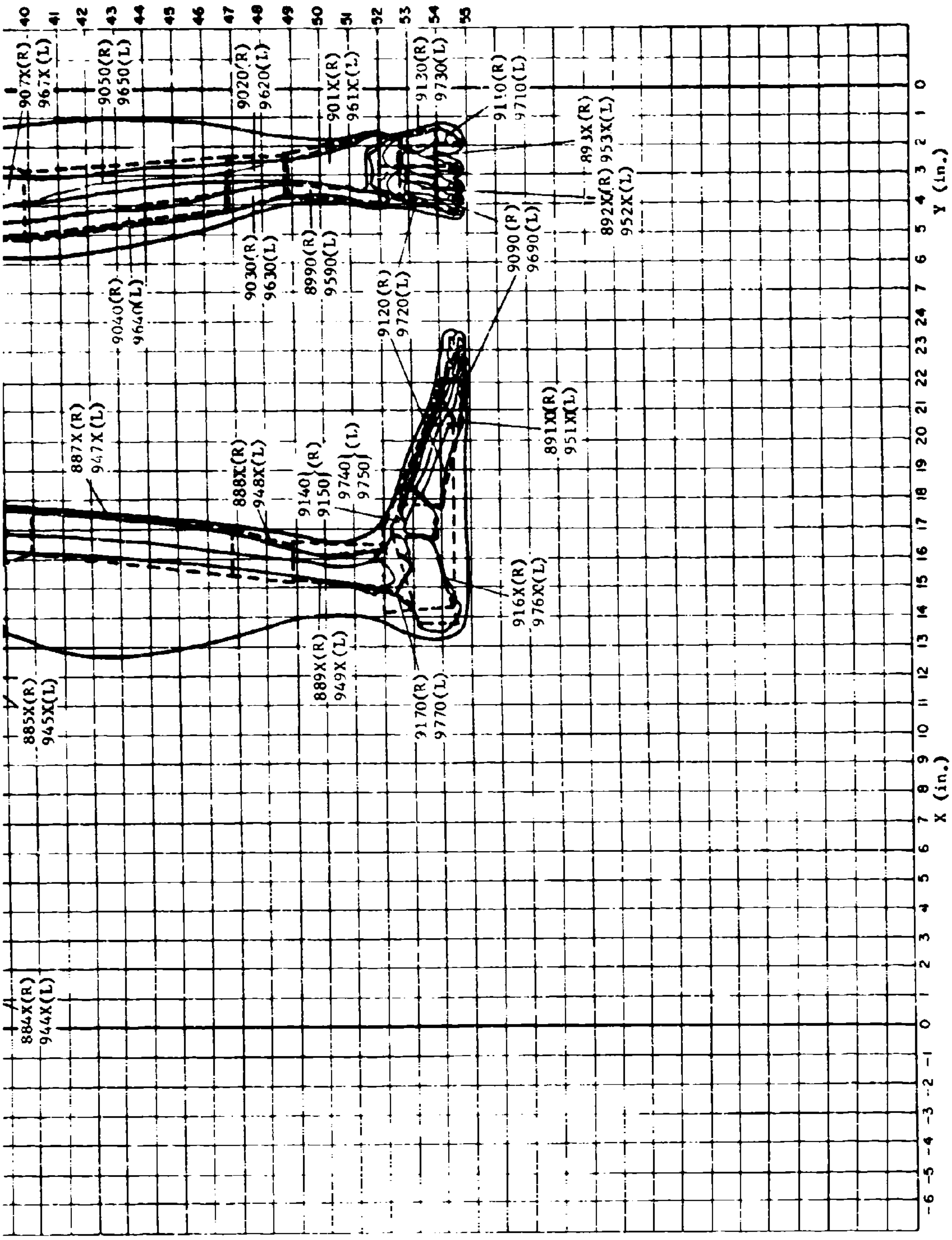


Figure 22 Composite Shields in the Skeleton, Seated Man

B

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13. ABSTRACT

(Distribution Limitation Statement No. 2)
The Computerized Anatomical Model Man is a detailed representation of the radiation transport properties of the human body. It is to be used for computation of the areal density distribution at specified locations in the body. This information is applicable to dose calculations in natural, weapon, reactor, and other radiation environments. The model has two configurations--standing and seated. Over 2200 individual geometrical shapes have been used to depict the external conformation, the skeleton, and the principal organs. The exterior dimensions are those of the 50th percentile Air Force man; the skeleton and organs were scaled from life-size models to conform to the exterior. The model includes variations of material density and fractional composition by weight due to the principal chemical elements contained in muscle, bone, bone marrow, and organ tissue. The model is compatible with the North American Rockwell Modified Elemental Volume Dose Program. This has been demonstrated by solution of sample problems employing both configurations of the model with the North American Rockwell Program on the CDC 6600 digital computer at the Air Force Weapons Laboratory.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Radiobiology						
Space radiation						
Spacecraft shielding						
Dose						
Depth dose						
Radiation hazards						
Radiation transport in man						